SEMICONDUCTOR SUBSTRATE PROCESSING APPARATUS AND METHOD

BACKGROUND OF THE INVENTION

Field of the Invention:

The present invention relates to a semiconductor substrate processing apparatus and method for forming circuit interconnects by filling a circuit pattern groove and/or hole formed in a semiconductor substrate with a plated metal film, and removing the plated metal film while leaving the metal film at the filled portion.

Description of the Related Art:

Generally, aluminum or aluminum alloys have been used as a material for forming interconnection circuits on a semiconductor substrate. The higher integration of semiconductor devices requires that a material having a higher electric conductivity should be used for interconnection circuits. Thus, there has been proposed a method which comprises plating a surface of a semiconductor substrate having a circuit pattern groove and/or hole formed therein to fill Cu (copper) or copper alloy into the circuit pattern groove and/or hole, and removing the Cu or copper alloy with the exception of the filled portion, thereby forming circuit interconnects.

The above method of forming circuit interconnects will be described with reference to FIGS. 1A through 1C. As shown in FIG. 1A, a conductive layer 101a is formed on a semiconductor substrate 101 on which semiconductor devices are formed, and an oxide film 102 of SiO_2 is deposited on the conductive layer 101a. Then, a via hole 103 and a trench 104 for an interconnect are formed in the

oxide film 2 by lithography and etching technology. Thereafter, a barrier layer 105 of TiN or the like is formed thereon, and then a seed layer 107 as an electric supply layer for electroplating is formed on the barrier layer 105.

Then, as shown in FIG. 1B, the surface of the semiconductor substrate W is coated with copper by electroplating to deposit a plated copper film 106 on the oxide film 102, thus filling the via hole 103 and the trench 104 with copper. Thereafter, the plated copper film 106 and the barrier layer 105 on the oxide film 102 are removed by chemical mechanical polishing (CMP), thus making the plated copper film 106 in the via hole 103 and the trench 104 lie flush with the oxide film 102. In this manner, an interconnect composed of the plated copper film 106 is produced as shown in FIG. 1C.

In this case, the barrier layer 105 is formed so as to cover a substantially entire surface of the oxide film 102, and the seed layer 107 is also formed so as to cover a substantially entire surface of the barrier layer 105. Thus, in some cases, as shown in FIG. 40, a copper film which is the seed layer 107 resides in a bevel (outer peripheral portion) of the semiconductor substrate W, or copper is deposited on an edge (outer peripheral portion) inwardly of the bevel of the semiconductor substrate W and remains unpolished (not shown in the drawing).

Copper can easily be diffused into the oxide film 102 in a semiconductor fabrication process such as annealing, thus deteriorating the electric insulation of the oxide film and impairing the adhesiveness of the oxide film with a film to be subsequently deposited to possibly cause separation of the

deposited film. It is therefore necessary to remove the remaining unnecessary copper completely from the substrate before at least film deposition. Furthermore, copper deposited on the outer peripheral portion of the substrate other than the circuit formation area is not only unnecessary, but may cause cross contamination in subsequent processes of delivering, storing and processing the substrate. For these reasons, it is necessary that the remaining deposited copper on the peripheral portion of the substrate should be completely removed immediately after the copper film deposition process or the CMP process.

Here, the outer peripheral portion of the substrate is defined as an area including an edge and a bevel of the semiconductor substrate W, or either the edge or the bevel. The edge of the substrate means areas of the front and back surfaces of the semiconductor substrate W within about 5 mm from the outer peripheral end of the substrate, and the bevel of the substrate means an area of the outer peripheral end surface and a curved portion in a cross section of the semiconductor substrate W within 0.5 mm from the outer peripheral end of the substrate.

Recently, a so-called dry-in dry-out configuration in which a substrate is introduced in a dry state and removed in a dry state is employed in a plating apparatus for performing Cu plating of copper interconnection, and a polishing apparatus for performing chemical mechanical polishing. The apparatuses have such structure that after respective processing steps such as plating or polishing are performed, particles are removed and dried by a cleaning unit and a spin-drying unit, and the semiconductor substrate is taken out in a dry state from the respective

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apparatuses. In this manner, the plating apparatus and the polishing apparatus perform many common processes, which are essentially successive processes. Thus, there have been problems that the initial cost and the running cost for the apparatuses are high, installation spaces for installation of both apparatuses need to be wide, and a long processing time is required.

Currently, the driving force for semiconductor devices is changing from work stations and personal computers to digital information household electric appliances (game machines, cellular phones, digital still cameras, DVD, car navigation instruments, digital video cameras, and the like). Under these circumstances, LSI production also needs to respond to changes from general purpose LSIs used in personal computers, and the like, to system LSIs required for digital information household electric appliances.

These system LSIs are characterized by a wide variety of products, low volume production, great fluctuations in the number of products made, and a short life of product, as compared with general purpose LSIs. In order to reduce the instrument costs of digital information household electrical appliances, it is indispensable to reduce the manufacturing cost for LSIs. In semiconductor production plants as well, it is demanded to shift from the concept of large scale lines to the possession of many types of small scale lines, and minimize the production time rather than the amount of production. In order to cope with these demands, it is demanded for future semiconductor device production to respond quickly to the needs of instrument manufacturers and place semiconductor devices on the production lines as promptly as

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possible. Besides, since changes in demand are drastic, it is necessary that functional changes can be made flexibly, or the apparatus can be renewed.

In the aforementioned process for forming interconnects using copper or copper alloys, electroless plating apparatuses are used in the formation of a seed layer, formation of a reinforcing seed layer formed on the seed layer for reinforcing the seed layer, and formation of an interconnect protective film.

Among these electroless plating apparatuses, instead of an electroless plating apparatus for performing electroless plating processes by providing a plurality of units for carrying out a plating step, a pretreatment step associated with plating, and a cleaning step, there has been proposed an electroless plating apparatus for performing the above electroless plating processes by one unit. FIG. 41 is a schematic view showing a schematic constitution of this type of electroless plating apparatus. As shown in FIG. 41, this electroless plating apparatus has a cover 83 disposed around a semiconductor substrate W placed on and fixed to a holding means 81 rotated by a motor M. While the semiconductor substrate W is being rotated by the motor M at a position shown by dotted lines, a plating liquid is supplied by a pump P from a plating tank 87 to the center of an upper surface of the semiconductor substrate W. While the plating liquid is spreaded on the entire upper surface of the semiconductor substrate W under a centrifugal force caused by the rotation of the semiconductor substrate W to carry out plating, the plating liquid, which has fallen from the semiconductor substrate W, is returned from a plating liquid recovery section 85 of the cover 83 to the plating

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tank 87. In this manner, the plating liquid is circulated. F denotes a filter.

On the other hand, the semiconductor substrate W which has been plated is rotated in such a state that the semiconductor substrate W is lowered to a position indicated by solid lines in FIG. 41, and cleaning water is supplied to the semiconductor substrate W from a cleaning water supply means (not shown). Thus, the plating liquid is rinsed out of the front surface of the semiconductor substrate W, collected into a cleaning liquid recovery section 86, and drained therefrom.

However, the above-described conventional electroless plating apparatus also has the following various problems:

(1) The plating liquid is always dripped onto the surface, to be plated, of the semiconductor substrate, and hence the plating liquid is used in a large amount by circulation. When a large amount of the plating liquid is used in a circulated manner, a large pump is required. A liquid temperature maintaining device, which counters a rise in the liquid temperature due to heat generation of the pump, is necessary. Thus, not only the apparatus cost increases, but also the apparatus becomes large-sized, and hence the cost for a clean room for accommodating this apparatus increases.

(2) The plating liquid is always used in circulation, and hence by-products are accumulated in the system on the basis of the principle of electroless plating, and a stable plating process cannot be maintained. In order to perform a stable plating process, analysis of the plating liquid, and a liquid adjustment device are necessary to thus increase the device cost and the clean room cost.

(3) Since a large amount of the plating liquid is used in circulation, particles tend to be generated from the respective components of the device. Thus, it is necessary to install a filter F in the circulation path to thus increase the device cost and the clean room cost.

(4) When plating is performed in such a state that the plating liquid is always supplied to only a certain portion on the surface to be plated, the thickness of the plated film at the portion where the plating liquid has been dripped is smaller than the thickness of the plated film at other portions, as confirmed by experiments. In this way, the uniformity of the film thickness on the substrate deteriorates. The reason is considered to possibly be that the portion where the plating liquid has been dripped is different from the other portions in terms of the flow velocity, thickness, or the like of the plating liquid, so that the reaction state at that portion differs.

(5) In order to perform electroless plating, the temperature of the surface of reaction between the surface to be plated and the plating liquid needs to be maintained at a predetermined constant temperature. Therefore, a measure for constantly heating a large amount of the plating liquid to a temperature optimal for a plating reaction needs to be taken. Thus, an increase in the apparatus cost and an increase in the clean room cost are induced. Moreover, since the plating liquid is constantly heated, deterioration of the plating liquid is promoted.

(6) The semiconductor substrate is always rotated, and hence heat dissipation due to the peripheral speed of the semiconductor substrate results in a conspicuous drop in temperature, leading

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to the failure to obtain a stable plating process.

In the aforementioned process for forming interconnects by copper or copper alloys, for example, the substrate processing steps of forming the film on the substrate, and polishing the film require that the reliability of substrate processing should be increased, for example, by making the film thickness constant, or controlling the film thickness at a desired value. The film thickness in the case of a semiconductor wafer, in particular, is in the range of about several tens of nanometers to several micrometers, and hence the film thickness must be controlled at such a minute level. From this point of view, a film thickness measuring device is installed in a substrate processing apparatus. In the CMP (chemical mechanical polishing) apparatus, it is also usual practice to embed a sensor for film thickness measurement in a turntable for performing polishing of the substrate and measure the film thickness during polishing.

However, in the case where the film thickness measuring device is installed in the substrate processing apparatus, the substrate is moved to the film thickness measuring device halfway through the substrate processing steps to measure the film thickness. Thus, there has been a problem that the time for measurement is required to thus decrease the throughput. Since the film thickness measuring device is provided in addition to the various devices for processing substrate, it has been necessary to ensure a space for installation of the film thickness measuring device.

In the CMP apparatus having a sensor for film thickness measurement embedded in a turntable, there have been problems that

mechanism becomes complicated, because the sensor is embedded in the turntable for performing polishing, and a slurry often adheres to the sensor to cause measurement to be difficult.

The above problems are not limited to the sensor for measurement of metal film thickness, and hold true for other various sensors for detection of substrate surface state, such as a sensor for detection of an insulating film thickness (oxide film thickness), a sensor for detection of presence or absence of a metallic thin film, a sensor for detection of presence or absence of particles on a substrate, and a sensor for recognition of a pattern formed on a substrate.

Generally, in a substrate processing apparatus, it is desirable not only to improve quality, but also to improve throughput from the viewpoint of productivity. Therefore, in order to meet demands from aspects of quality and productivity, detection of a substrate surface condition such as film thickness needs to be performed in a series of movement of a substrate during the process so as not to lower throughput.

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SUMMARY OF THE INVENTION

The present invention has been made in view of the above drawbacks. It is therefore a first object of the invention to provide a semiconductor substrate processing apparatus and method which can lower the initial cost and the running cost of the apparatus, do not need a wide installation space, can form circuit interconnects by copper or copper alloy in a short processing time, and are free from remaining copper film at an edge and bevel portion which will cause cross contamination.

Another object of the present invention is to provide a semiconductor substrate processing apparatus suitable for production lines which produce products in many different varieties, in a low volume, in greatly fluctuated numbers, and with a short product life, such as system LSIs used in digital information household electric appliances, are on a small scale, and can flexibly make functional changes or can renew the apparatus.

A second object of the present invention is to provide an electroless plating method and apparatus which can reduce the amount of a plating liquid used, can maintain a stable plating process, can achieve a small size and a low cost of the apparatus, can attain the uniformity of a film thickness on the plane, and can prevent deterioration of a plating liquid due to a temperature rise.

A third object of the present invention is to provide a substrate processing apparatus which can perform detection of various substrate surface states, such as film thickness, easily and highly accurately during transporting or processing of the substrate, without stopping transporting or processing of the substrate, so as not to lower throughput.

In order to achieve the first object, a first aspect of the present invention, comprising: a carry-in and carry-out section for carrying in and carrying out a semiconductor substrate having a surface on which a circuit is formed, in a dry state; a plated metal film forming unit for forming a plated metal film on the semiconductor substrate which has been carried in; a bevel etching unit for etching a peripheral edge portion of the semiconductor substrate; a polishing unit for polishing at least part of the

plated metal film on the semiconductor substrate; and a transport mechanism for transporting the semiconductor substrate between the units.

According to the present invention, the steps of removing a plated metal film at an edge portion and a bevel portion after formation of the plated metal film, and polishing the plated metal film on the semiconductor substrate can be performed continuously by one apparatus.

The present invention, comprising: a carry-in and carry-out section for carrying in and carrying out a semiconductor substrate having a surface on which a circuit is formed, in a dry state; a plated metal film forming unit for forming a plated metal film on the semiconductor substrate which has been carried in; a bevel etching unit for etching a peripheral edge portion of the semiconductor substrate; a polishing unit for polishing at least part of the plated metal film on the semiconductor substrate; and a transport mechanism for transporting the semiconductor substrate between the units; wherein the plated metal film forming unit and the bevel etching unit are interchangeable.

The present invention, comprising: a carry-in and carry-out section for carrying in and carrying out a semiconductor substrate having a surface on which a circuit is formed, in a dry state; a plated metal film forming unit for forming a plated metal film on the semiconductor substrate which has been carried in; a bevel etching unit for etching and removing at least one of the plated metal film, a seed layer and a barrier layer formed at a peripheral edge portion of the semiconductor substrate; an annealing unit for annealing the semiconductor substrate; and a

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transport mechanism for transporting the semiconductor substrate between the units.

The present invention, comprising: a carry-in and carry-out section for carrying in and carrying out a semiconductor substrate having a surface on which a circuit is formed, in a dry state; a plated metal film forming unit for forming a plated metal film on the semiconductor substrate which has been carried in; a polishing unit for polishing at least part of the plated metal film on the semiconductor substrate; and a transport mechanism for transporting the semiconductor substrate between the units; wherein in the plated metal film forming unit, plating treatment and cleaning treatment are performed in such a state that the semiconductor substrate is held by a substrate holding portion.

The present invention, comprising: a carry-in and carry-out section for carrying in and carrying out a semiconductor substrate having a surface on which a circuit is formed, in a dry state; a plated metal film forming unit for forming a plated metal film on the semiconductor substrate which has been carried in; a polishing unit for polishing at least part of the plated metal film on the semiconductor substrate; and a transport mechanism for transporting the semiconductor substrate between the units; wherein the plated metal film forming unit comprises a substrate holding portion for holding the semiconductor substrate, an anode disposed above a surface, to be plated, of the substrate, and a cathode electrode for passing an electric current in contact with the substrate, and performs plating while a plating liquid impregnated material comprising a water retaining material is placed in a space formed between the surface to be plated and the

anode.

The present invention, comprising: a carry-in and carry-out section for carrying in and carrying out a semiconductor substrate having a surface on which a circuit is formed, in a dry state; a plated metal film forming unit for forming a plated metal film on the semiconductor substrate which has been carried in; a polishing unit for polishing at least part of the plated metal film on the semiconductor substrate; and a transport mechanism for transporting the semiconductor substrate between the units; wherein in the plated metal film forming unit, plating treatment, and cleaning and drying treatment are performed by raising and lowering the semiconductor substrate so as to correspond to respective operating positions, while the semiconductor substrate is held by a substrate holding portion.

The present invention, comprising: a carry-in and carry-out section for carrying in and carrying out a semiconductor substrate having a surface on which a circuit is formed, in a dry state; a plated metal film forming unit for forming a plated metal film on the semiconductor substrate which has been carried in; a polishing unit for polishing at least part of the plated metal film on the semiconductor substrate; and a transport mechanism for transporting the semiconductor substrate between the units; wherein the plated metal film forming unit holds the semiconductor substrate such that a surface, to be plated, of the semiconductor substrate faces upward, seals a peripheral edge portion of the surface, to be plated, of the semiconductor substrate with a seal in a watertight manner, has an anode disposed above the surface to be plated in proximity to the surface to be plated, has a cathode

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electrode for passing an electric current in contact with the semiconductor substrate, and performs plating while a plating liquid is held in a space formed by the surface, to be plated, of the semiconductor substrate and the seal.

The present invention, comprising: a carry-in and carry-out section for carrying in and carrying out a semiconductor substrate having a surface on which a circuit is formed, in a dry state; a plated metal film forming unit for forming a plated metal film on the semiconductor substrate which has been carried in; a polishing unit for polishing at least part of the plated metal film on the semiconductor substrate; and a transport mechanism for transporting the semiconductor substrate between said units; wherein said plated metal film forming unit comprises a substrate holding portion for holding the semiconductor substrate such that a surface, to be plated, of the semiconductor substrate faces upward, an anode disposed above the surface, to be plated, of the semiconductor substrate, a cathode electrode for passing an electric current in contact with the semiconductor substrate, and a pure water supply nozzle, and simultaneously cleans the semiconductor substrate and said cathode electrode by supplying pure water from said nozzle after completion of plating treatment.

The present invention, comprising: a carry-in and carry-out section for carrying in and carrying out a semiconductor substrate having a surface on which a circuit is formed, in a dry state; a plated metal film forming unit for forming a plated metal film on the semiconductor substrate which has been carried in; a polishing unit for polishing at least part of the plated metal film on the semiconductor substrate; and a transport mechanism for

transporting the semiconductor substrate between the units; wherein the plated metal film forming unit holds the semiconductor substrate such that a surface, to be plated, of the semiconductor substrate faces upward, seals a peripheral edge portion of the surface, to be plated, of the semiconductor substrate with a seal in a watertight manner, has an anode disposed above the surface to be plated in proximity to the surface to be plated, has a cathode electrode for passing an electric current in contact with the semiconductor substrate, and performs plating while a plating liquid is held in a space sealed in a watertight manner and formed between the surface to be plated and the anode.

The present invention, comprising: a carry-in and carry-out section for carrying in and carrying out a semiconductor substrate having a surface on which circuit is formed, in a dry state; a plated metal film forming unit for forming a plated metal film on the semiconductor substrate which has been carried in; a polishing unit for polishing at least part of the plated metal film on the semiconductor substrate; and a transport mechanism for transporting the semiconductor substrate between the units; wherein the plated metal film forming unit can perform pretreatment, plating treatment, and water washing treatment.

The present invention, comprising: a carry-in and carry-out section for carrying in and carrying out a semiconductor substrate having a surface on which a circuit is formed, in a dry state; a barrier layer forming unit for forming a barrier layer on the semiconductor substrate which has been carried in; a seed layer forming unit for forming a seed layer on the barrier layer; a plated metal film forming unit for forming a plated metal film

on the seed layer; a bevel etching unit for etching and removing a metal film formed at an edge portion of the semiconductor substrate; an annealing unit for annealing the plated metal film; a polishing unit for polishing the plated metal film and/or the seed layer on the semiconductor substrate; a cleaning unit for cleaning and drying the semiconductor substrate whose plated metal film has been polished; a cover plating unit for forming a plated cover layer on the plated metal film; and a transport mechanism for transporting the semiconductor substrate; wherein the barrier layer forming unit, the seed layer forming unit, the plated metal film forming unit, the bevel etching unit, the annealing unit, the polishing unit, the cleaning unit, and the cover plating unit are interchangeable.

By constituting the semiconductor substrate processing apparatus as described above, processing in which metal plating is applied onto a semiconductor substrate having a groove and/or a hole for a wiring pattern formed on a surface thereof, and having a barrier layer and a power supply seed layer formed thereon, a plated metal film is polished and removed, and the substrate is cleaned and dried to form interconnects, can be performed continuously by one apparatus. Thus, compared with a case in which respective processing steps are performed by separate apparatuses, the entire apparatus can be compact, a wide installation space is not needed, the initial cost and running cost for the apparatus can be decreased, and interconnects can be formed in a short processing time.

According to the present invention, there is provided a semiconductor substrate processing apparatus, comprising: a

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carry-in and carry-out section for carrying in and carrying out a semiconductor substrate, which has a groove and/or a hole for a wiring pattern formed on a surface thereof, and has a barrier layer formed thereon, in a dry state; a seed layer forming section for forming a power supply seed layer on the semiconductor substrate, which has been carried in, by electroless plating; a plated metal film forming section for forming a plated metal film on the semiconductor substrate, on which the power supply seed layer has been formed, by electroplating; a polishing section for polishing and removing the plated metal film, the power supply seed layer, and the barrier layer, while retaining a portion filled into the groove and/or the hole of the semiconductor substrate on which the plated metal film has been formed; a cleaning section for cleaning and drying the semiconductor substrate from which the respective layers are removed; and a transfer mechanism for transferring the semiconductor substrate between the respective sections.

By constituting the semiconductor substrate processing apparatus as described above, processing in which a power supply seed layer and a plated metal film are applied onto a semiconductor substrate having a groove and/or a hole for a wiring pattern formed on a surface thereof, and having a barrier layer formed thereon, the power supply seed layer and the plated metal film are polished and removed, and the substrate is cleaned and dried to form interconnects, can be performed continuously by one apparatus. Thus, compared with a case in which respective treatment steps are performed by separate apparatuses, the entire apparatus can be compact, a wide installation space is not needed, the initial cost and running cost for the apparatus can be decreased, and

interconnects can be formed in a short processing time.

According to the present invention, there is provided a semiconductor substrate processing apparatus, comprising: a carry-in and carry-out section for carrying in and carrying out a semiconductor substrate, which has a groove and/or a hole for a wiring pattern formed on a surface thereof, in a dry state; a barrier layer forming section for forming a barrier layer on the semiconductor substrate which has been carried in; a seed layer forming section for forming a power supply seed layer on the semiconductor substrate on which the barrier layer has been formed, by electroless plating; a plated metal film forming section for forming a plated metal film on the semiconductor substrate on which the power supply seed layer has been formed, by electroplating; a polishing section for polishing and removing the plated metal film, the power supply seed layer, and the barrier layer, while retaining a portion filled into the groove and/or the hole of the semiconductor substrate on which the plated metal film has been formed; a cleaning section for cleaning and drying the semiconductor substrate from which the respective layers are removed; and a transfer mechanism for transferring the semiconductor substrate between the respective sections.

By constituting the semiconductor substrate processing apparatus as described above, processing in which a barrier layer, a power supply seed layer and a plated metal film are applied onto a semiconductor substrate having a groove and/or a hole for a wiring pattern formed on a surface thereof, the barrier layer, the power supply seed layer and the plated metal film are polished and removed, and the substrate is cleaned and dried to form interconnects, can

be performed continuously by one apparatus. Thus, compared with a case in which respective treatment steps are performed by separate apparatuses, the entire apparatus can be compact, a wide installation space is not needed, the initial cost and running cost for the apparatus can be decreased, and interconnects can be formed in a short processing time.

According to the present invention, there are provided a film thickness measuring section for measuring the film thickness of a plated metal film after formation of the plated metal film, a remaining film measuring section for measuring a remaining film after polishing and removing operation, and recording means for recording results of measurements by the film thickness measuring section and the remaining film measuring section.

According to the present invention, a film thickness measuring section for measuring the film thicknesses of the respective layers is provided, and the initial film thicknesses of the respective layers are measured and the results of the measurements are recorded into the recording means.

By providing the recording means and recording the results of measurement of the film thicknesses, the remaining film, and the initial film thicknesses of the respective layers measured with the film thickness measuring section and the remaining film measuring section, it is possible to utilize the records as data for controlling the processing time of a subsequent step, and as data for judging the good or poor state of each processing step, or judging whether the semiconductor substrate after completion of the interconnects formation treatment is good or poor.

According to the present invention, there is provided a

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semiconductor substrate processing apparatus, comprising: a carry-in and carry-out section for carrying in and carrying out a semiconductor substrate, which has a groove and/or a hole for a wiring pattern formed on a surface thereof, in a dry state; a metal plating unit for forming a plated metal film on the semiconductor substrate which has been carried in; a polishing unit for polishing the plated metal film on the semiconductor substrate; a cleaning unit for cleaning and drying the semiconductor substrate whose plated metal film has been polished; and a transport mechanism for transporting the semiconductor substrate; wherein the metal plating unit and the cleaning unit are adapted to be interchangeable.

Since the metal plating unit and the cleaning unit are adapted to be interchangeable as described above, a change in the substrate treatment process can be easily performed, and renewal of the function of the entire substrate processing apparatus can be achieved at a low cost in a short time.

According to the present invention, a bevel etching unit for etching and removing the plated metal film formed at an edge (bevel) portion of the semiconductor substrate is provided, and the metal plating unit, the cleaning unit and the bevel etching unit are adapted to be interchangeable.

By providing the bevel etching unit, the plated metal film at the edge and bevel portions, which becomes the cause of cross contamination, can be removed. Since the metal plating unit, the cleaning unit and the bevel etching unit are adapted to be interchangeable, renewal of the function of the entire substrate processing apparatus can be achieved at a low cost in a short time,

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as in the above-mentioned case.

The present invention, comprising: a carry-in and carry-out section for carrying in and carrying out a semiconductor substrate, which has a circuit formed on a surface thereof, in a dry state; a plated metal film forming unit for forming a plated metal film on the semiconductor substrate which has been carried in; an annealing unit for annealing the semiconductor substrate; a polishing unit for polishing at least part of the plated metal film on the semiconductor substrate; and a transport mechanism for transporting the semiconductor substrate between the units.

According to the present invention, there is provided an annealing unit for annealing the plated metal film.

Since the annealing unit is provided, as described above, the adhesive force of the plated metal film is stable, there is no fear that the plated metal film may peel during polishing, and electrical characteristics of the plated metal film are improved.

According to the present invention, there is provided a film thickness measuring instrument for measuring the film thickness of the film formed on the semiconductor substrate.

By measuring the film thickness as described above, the plating time for obtaining the desired plated film thickness, the polishing time, and the annealing time can be adjusted.

According to the present invention, there is provided a seed layer forming unit for forming a seed layer on the semiconductor substrate.

By integrating the seed layer forming unit with the plating unit, the time required for movement of the substrate between the apparatuses can be saved, throughput can be improved, and

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contamination-free film formation can be performed.

According to the present invention, there is provided a barrier layer forming unit for forming a barrier layer on the semiconductor substrate.

By integrating the barrier layer forming unit with the plating unit, the time required for movement of the substrate between the apparatuses can be saved, and throughput can be improved.

According to the present invention, there is provided a cover plating unit.

By providing the cover plating unit as described above, a cover plating for preventing oxidation or degradation of a plated metal film can be applied onto the upper surface of the plated metal film, so that oxidation and degradation of the upper surface of the plated metal film can be prevented.

According to the present invention, there is provided a semiconductor substrate processing apparatus, comprising: a carry-in and carry-out section for carrying in and carrying out a semiconductor substrate, which has a groove and/or a hole for a wiring pattern formed on a surface thereof, in a dry state; a metal plating unit for forming a plated metal film on the semiconductor substrate which has been carried in; a polishing unit for polishing the plated metal film on the semiconductor substrate; a cleaning unit for cleaning and drying the semiconductor substrate whose plated metal film has been polished; and a transport mechanism for transporting the semiconductor substrate; wherein the metal plating unit has a cathode portion having a substrate holding portion for holding the substrate with a surface, to be plated,

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facing upward, an electrode arm portion disposed above the cathode portion and having an anode, and plating liquid pouring means for pouring a plating liquid into a space between the surface, to be plated, of the substrate held by the substrate holding portion and the anode of the electrode arm portion located in proximity to the surface to be plated.

The cathode portion of the metal plating unit has the substrate holding portion for holding the substrate horizontally in such a state that the surface to be plated faces upward. Thus, plating treatment can be performed, and other treatments associated with plating treatment, such as pretreatment and cleaning and drying treatment, can be performed before and after plating treatment.

According to the present invention, there is provided a semiconductor substrate processing apparatus, comprising a carry-in and carry-out section for carrying in and carrying out a semiconductor substrate, which has a groove and/or a hole for a wiring pattern formed on a surface thereof, in a dry state; a metal plating unit for forming a plated metal film on the semiconductor substrate which has been carried in; a polishing unit for polishing the plated metal film on the semiconductor substrate; a cleaning unit for cleaning and drying the semiconductor substrate whose plated metal film has been polished; and a transport mechanism for transporting the semiconductor substrate; wherein the metal plating unit can perform precoating treatment, plating treatment and water washing treatment.

As described above, the metal plating unit can perform precoating treatment, plating treatment and water washing

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treatment, and particularly water washing treatment after plating treatment is performed in the metal plating unit. Thus, the plating liquid is not brought into other units.

The present invention, comprising: a carry-in and carry-out section for carrying in and carrying out a semiconductor substrate, which has a groove and/or a hole for a wiring pattern formed on a surface thereof, in a dry state; a barrier layer forming unit for forming a barrier layer on the semiconductor substrate which has been carried in; a seed layer forming unit for forming a seed layer on the barrier layer; a metal plating unit for forming a plated metal film on the seed layer; a bevel etching unit for etching and removing a metal film formed at an edge portion of the semiconductor substrate; an annealing unit for annealing the plated metal film; a polishing unit for polishing the plated metal film and/or the seed layer on the semiconductor substrate; a cleaning and drying unit for cleaning and drying the semiconductor substrate whose plated metal film has been polished; a plating unit for forming a plated cover film on the plated metal film; and a transport mechanism for transporting the semiconductor substrate; wherein the barrier layer forming unit, the seed layer forming unit, the metal plating unit, the bevel etching unit, the annealing unit, the polishing unit, the cleaning unit, and the cover plating unit are interchangeable.

Since the respective units are adapted to be interchangeable, as described above, various changes in the substrate processing process can be easily performed, and renewal of the function of the entire substrate processing apparatus can be achieved at a low cost in a short time.

According to the present invention, there is provided a semiconductor substrate processing method, comprising: carrying in a semiconductor substrate, which has a groove and/or a hole for a wiring pattern formed on a surface thereof, and having a barrier layer formed thereon, in a dry state by a carry-in and carry-out mechanism; forming a power supply seed layer on the semiconductor substrate which has been carried in; forming a plated metal film thereon; polishing and removing the plated metal film, the power supply seed layer, and the barrier layer, while retaining a portion filled into the groove and/or the hole of the semiconductor substrate on which the plated metal film has been formed; cleaning and drying the semiconductor substrate from which the respective layers are removed; and then transferring the semiconductor substrate in a dry state to the carry-in and carry-out mechanism.

By performing the semiconductor substrate treatment method as described above, processing in which a power supply seed layer and a plated metal film are applied onto a semiconductor substrate having a groove and/or a hole for a wiring pattern formed on a surface thereof, and having a barrier layer formed thereon, the power supply seed layer and the plated metal film are polished and removed, and the substrate is cleaned and dried to form interconnects, can be performed continuously. Thus, interconnects can be formed in a short processing time.

According to the present invention, there is provided a semiconductor substrate processing method, comprising: carrying in a semiconductor substrate, which has a groove and/or a hole for a wiring pattern formed on a surface thereof, in a dry state by a carry-in and carry-out mechanism; forming a barrier layer on the

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semiconductor substrate which has been carried in; forming a power supply seed layer thereon; forming a plated metal film further thereon; polishing and removing the plated metal film, the power supply seed layer and the barrier layer, while retaining a portion filled into the groove and/or the hole of the semiconductor substrate on which the plated metal film has been formed; cleaning and drying the semiconductor substrate from which the respective layers are removed; and then transferring the semiconductor substrate in a dry state to the carry-in and carry-out mechanism.

By performing the semiconductor substrate processing method as described above, processing in which a barrier layer, a power supply seed layer and a plated metal film are applied onto a semiconductor substrate having a groove and/or a hole for a wiring pattern formed on a surface thereof, the power supply seed layer and the plated metal film are polished and removed, and the semiconductor substrate is cleaned and dried to form interconnects, can be performed continuously. Thus, interconnects can be formed in a short processing time.

In order to achieve the second object, a second aspect of the present invention is characterized by continuously performing the steps of: holding a substrate with a surface to be plated facing upward by holding means having a mechanism for holding an electroless plating treatment liquid on the substrate; supplying the electroless plating treatment liquid onto the surface, to be plated, of the substrate; and performing electroless plating treatment while storing and holding the electroless plating treatment liquid on the surface, to be plated, of the substrate for a predetermined time. Thus, treatment of the surface to be

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plated can be performed using a small amount of the electroless plating treatment liquid, a pump of a small size can be used as a pump for supplying the electroless plating treatment liquid, the electroless plating apparatus can be made compact, and the cost for a clean room housing the electroless plating apparatus can be reduced. Since a small amount of the electroless plating treatment liquid is used, heating and warmth retention of the electroless plating treatment liquid are easy, and can be performed immediately.

The present invention is characterized in that the step of bringing the electroless plating treatment liquid supplied onto the surface, to be plated, of the substrate into contact with the surface, to be plated, of the substrate is provided between the step of supplying the electroless plating treatment liquid and the step of performing electroless plating treatment while storing and holding the electroless plating treatment liquid on the surface, to be plated, of the substrate for a predetermined time. The step of bringing the electroless plating treatment liquid, which has been supplied onto part of the surface, to be plated, of the substrate, into contact with the entire surface to be plated comprises moving the substrate (namely, for example, rotating, vibrating, or swaying (rocking) the substrate supplied with the electroless plating treatment liquid), or moving the supplied electroless plating treatment liquid (e.g., raking the electroless plating treatment liquid using a raking member, or feeding air to the surface of the liquid).

The present invention is characterized in that the step of performing electroless plating treatment while storing and holding

the electroless plating treatment liquid on the surface, to be plated, of the substrate for a predetermined time is performed in such a state that the substrate is in a stationary state. With this construction, heat dissipation due to the peripheral speed of the substrate does not take place, the reaction temperature of respective portions can be uniformized, and a stable process can be obtained, compared with a case in which the treatment is performed in such a state that the substrate is rotated.

The present invention is characterized in that the plated surface after treatment with the electroless plating treatment liquid is cleaned by pouring a cleaning liquid, and is then spin-dried.

According to the present invention, there is provided an electroless plating method for treating a surface, to be plated, of a substrate by bringing an electroless plating treatment liquid in contact with the surface to be plated, characterized in that: the electroless plating treatment liquid is contacted with the surface, to be plated, of the substrate in such a state that the substrate is heated to a temperature higher than electroless plating treatment temperature, and/or the electroless plating treatment liquid is contacted with the surface, to be plated, of the substrate in such a state that the temperature of an atmosphere for performing electroless plating is substantially equal to electroless plating treatment temperature. With this constitution, the temperature of the plating liquid requiring a great electric power consumption for heating need not be raised so much, and hence the electric power consumption can be decreased, and change of the composition of the plating liquid can be

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prevented.

The present invention, comprising: holding means for holding a substrate with a surface thereof to be plated facing upward; a plating liquid holding mechanism for sealing the periphery of the surface, to be plated, of the substrate held by the holding means; and electroless plating treatment liquid supply means for supplying an electroless plating treatment liquid to, and storing the electroless plating treatment liquid on, the surface, to be plated, of the substrate sealed with the plating liquid holding mechanism. This electroless plating apparatus can use a pretreatment liquid, a catalytic treatment liquid, an electroless plating liquid or the like as the electroless plating treatment liquid while switching any of these liquids, and can carry out a series of electroless plating steps in a single cell.

The present invention, comprising: holding means for holding a substrate with a surface thereof to be plated facing upward; and electroless plating treatment liquid supply means for supplying an electroless plating treatment liquid to the surface, to be plated, of the substrate; the electroless plating treatment liquid supply means being provided above the surface to be plated, and adapted to supply the electroless plating treatment liquid in a scattered state. Thus, the treatment liquid can be simultaneously supplied to the entire surface, to be plated, of the substrate substantially uniformly.

The present invention is characterized in that heating means is provided close to the substrate. As the heating means, for example, a backside heater for heating the surface to be plated from a lower surface side of the substrate is provided, or a lamp

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heater for heating the surface to be plated from an upper surface side of the substrate is provided.

In order to achieve the third object, according to a third aspect of the present invention, there is provided a substrate processing apparatus having substrate holding means for holding a substrate and adapted to perform transportation or treatment of the substrate while holding the substrate by the substrate holding means, characterized in that a sensor for detecting substrate surface state such as a metal film thickness, is provided in the substrate holding means, and the state of a substrate surface is detected based on a signal detected by the sensor during transportation or treatment of the substrate. Thus, the substrate surface state such as the metal film thickness of the substrate can be detected without stopping or interrupting the substrate treatment process, and the substrate surface state can also be detected, while high throughput is actualized.

According to the present invention, there is also provided a substrate processing apparatus having substrate holding means for holding a substrate and adapted to perform transportation or treatment of the substrate while holding the substrate by the substrate holding means, characterized in that a sensor for detecting substrate surface state is provided at a predetermined position where the substrate makes an approach during transportation or treatment of the substrate by the substrate holding means, and the state of a substrate surface is detected based on a signal detected by the sensor when the substrate approaches the sensor. The sensor is preferably movable, and it is desirable that the distance between the substrate and the sensor

can be arbitrarily set according to the purpose of detection.

According to the present invention, there is also provided a substrate processing apparatus having substrate holding means for holding a substrate and a substrate treatment module for treating the substrate, and adapted to carry the substrate, which has been held by the substrate holding means, into or out of the substrate treatment module, characterized in that a sensor for detecting substrate surface state is provided near a substrate carry-in and carry-out opening of the substrate treatment module, or near a position in the substrate treatment module where the substrate is treated, and the state of a substrate surface is detected based on a signal from the sensor when the substrate is carried into or carried out of the substrate treatment module, or when the substrate is treated in the substrate treatment module.

The sensor is not limited to a sensor for measuring metal film thickness. As the sensor, other various sensors for detecting substrate surface state, such as a sensor for detection of an insulating film thickness (oxide film thickness), a sensor for detection of presence or absence of a metallic thin film, a sensor for detection of presence or absence of particles on a substrate, and a sensor for recognition of a pattern formed on a substrate, may be used.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1A to 1C are schematic views for forming interconnects on a semiconductor substrate;

FIG. 2 is a view showing a plan constitution example of a semiconductor substrate processing apparatus according to the

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present invention;

FIG. 3 is a view showing a schematic constitution example of a polishing table and a top ring in the semiconductor substrate processing apparatus according to the present invention;

FIG. 4 is a view showing a schematic constitution example of a cleaning machine in the semiconductor substrate processing apparatus according to the present invention;

FIG. 5 is a view showing a schematic constitution example of a cleaning machine of the polishing table in the semiconductor substrate processing apparatus according to the present invention;

FIGS. 6A to 6C are views showing a robot in the semiconductor substrate processing apparatus according to the present invention, and FIG. 6A is a view showing an appearance, FIG. 6B is a plan view of a robot hand, and FIG. 6C is a cross-sectional view of the robot hand;

FIG. 7 is a view showing a plan constitution of a plated Cu film forming unit in the semiconductor substrate processing apparatus according to the present invention;

FIG. 8 is a cross-sectional view taken along line A-A of FIG. 7;

FIG. 9 is a view showing a sectional constitution of a substrate holding portion and a cathode portion of the plated Cu film forming unit in the semiconductor substrate processing apparatus according to the present invention;

FIG. 10 is a view showing a sectional constitution of an electrode arm portion of the plated Cu film forming unit in the semiconductor substrate processing apparatus according to the present invention;

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FIG. 11 is a schematic view showing an anode and a plating liquid impregnated material according to another embodiment of the present invention;

FIG. 12 is a schematic view showing an anode and a plating liquid impregnated material according to another embodiment of the present invention;

FIG. 13 is a view showing a plan constitution example of the semiconductor substrate processing apparatus according to the present invention;

FIG. 14 is a view showing a plan constitution example of the semiconductor substrate processing apparatus according to the present invention;

FIG. 15 is a view showing a plan constitution example of the semiconductor substrate processing apparatus according to the present invention;

FIG. 16 is a view showing a plan constitution example of the semiconductor substrate processing apparatus according to the present invention;

FIG. 17 is a view showing a flow of the respective steps in the semiconductor substrate processing apparatus illustrated in FIG. 16;

FIG. 18 is a view showing a schematic plan constitution example of an aligner and film thickness measuring instrument in the semiconductor substrate processing apparatus according to the present invention;

FIG. 19 is a view showing a side constitution example of the aligner and film thickness measuring instrument of the semiconductor substrate processing apparatus according to the

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present invention;

FIG. 20 is a view showing movement of a semiconductor substrate in the aligner and film thickness measuring instrument illustrated in FIGS. 18 and 19;

FIG. 21 is a view showing a schematic constitution example of a bevel and backside cleaning unit in the semiconductor substrate processing apparatus according to the present invention;

FIGS. 22A to 22D are views showing base plate constitution examples for placing respective units in the semiconductor substrate processing apparatus according to the present invention;

FIGS. 23A and 23B are views showing schematic front constitution examples of the respective units in the semiconductor substrate processing apparatus according to the present invention;

FIGS. 24A and 24B are views showing schematic front constitution examples of the respective units in the semiconductor substrate processing apparatus according to the present invention;

FIG. 25 is a view showing a plan constitution example of the semiconductor substrate processing apparatus according to the present invention;

FIGS. 26A to 26C are schematic views showing an example of a plating step;

FIG. 27 is a view showing a schematic constitution of an electroless plating apparatus using an embodiment of the present invention;

FIG. 28 is a view showing a schematic constitution of an electroless plating apparatus using another embodiment of the present invention;

FIGS. 29A and 29B are views showing the results of

measurement of the film thicknesses of semiconductor substrates which are electroless-plated by the methods of the present invention and a conventional example;

FIG. 30 is a plan view showing an example of a plating apparatus to which the present invention is applied;

FIG. 31 is a plan view showing an example of a CMP apparatus to which the present invention is applied;

FIG. 32 is a view showing an example of a plating and CMP apparatus to which the present invention is applied;

FIG. 33 is a perspective view showing a transfer robot;

FIGS. 34A and 34B are views showing a robot hand attached to the transfer robot, and FIG. 34A is a plan view and FIG. 34B is a side sectional view;

FIGS. 35A and 35B are views showing a transfer robot to which the present invention is applied, and FIG. 35A is a schematic plan view and FIG. 35B is a schematic side view;

FIGS. 36A and 36B are views showing an example to which the present invention is applied, and FIG. 36A is a schematic plan view and FIG. 36B is a schematic side view;

FIG. 37 is a schematic front view of the neighborhood of a reversing machine to which the present invention is applied;

FIG. 38 is a plan view of a reversing arm portion;

FIG. 39 is a sectional view of an essential part of a plating module to which the present invention is applied;

FIG. 40 is a view showing a state in which a seed layer and a barrier layer have remained in a bevel portion as a result of CMP performed without bevel etching process of a semiconductor substrate;

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FIG. 41 is a view showing a schematic constitution of a conventional electroless plating apparatus;

FIG. 42 is a view showing a schematic constitution of an electroplating apparatus according to the present invention;

FIG. 43 is a view showing a schematic constitution of an electroplating apparatus according to the present invention;

FIG. 44 is a view showing a schematic constitution of an electroplating apparatus according to the present invention;

FIG. 45 is a plan view of a state in which a housing has been removed from an electrode portion of the electrode arm shown in FIG. 10;

FIG. 46 is a plan view schematically showing a state in which a plating liquid is spreading throughout the surface, to be plated, of a substrate when plating is performed using the plated Cu film forming unit illustrated in FIG. 10;

FIGS. 47A and 47B are views of different modifications of FIG. 46, each schematically showing a state in which a plating liquid is spreading throughout the surface, to be plated, of the substrate;

FIG. 48 is a view showing a schematic constitution of an electroplating apparatus to which an embodiment of the present invention is applied;

FIG. 49 is a schematic view of an essential part showing a portion close to an outer peripheral portion of a plating liquid impregnated material in the electroplating apparatus;

FIGS. 50A and 50B are views showing other embodiments of the present invention; and

FIG. 51 is an electrical equivalent circuit of an

electrolytic treatment apparatus applied to the electroplating apparatus of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A first aspect of the present invention will now be described with reference to FIGS. 2 to 25 and FIGS. 42 to 51. FIG. 2 is a view showing the plan constitution of a semiconductor substrate processing apparatus according to the first aspect of the present invention. The semiconductor substrate processing apparatus of the present invention is of a constitution in which there are provided a loading and unloading section 1, a plated Cu film forming unit 2, a first robot 3, a third cleaning machine 4, a reversing machine 5, a reversing machine 6, a second cleaning machine 7, a second robot 8, a first cleaning machine 9, a first polishing apparatus 10, and a second polishing apparatus 11. A before-plating and after-plating film thickness measuring instrument 12 for measuring the film thicknesses before and after plating, and a dry state film thickness measuring instrument 13 for measuring the film thickness of a semiconductor substrate W in a dry state after polishing are placed near the first robot 3.

The before-plating and after-plating film thickness measuring instrument 12, and the dry state film thickness measuring instrument 13, especially the dry state film thickness measuring instrument 13, may be provided on a hand of the first robot 3, as will be described later on. The before-plating and after-plating film thickness measuring instrument 12 may be provided at a semiconductor substrate carry-in and carry-out opening of the plated Cu film forming unit 2, although this is not shown, so as

to measure the film thickness of the semiconductor substrate W carried in, and the film thickness of the semiconductor substrate W carried out.

The first polishing apparatus (polishing unit) 10 has a polishing table 10-1, a top ring 10-2, a top ring head 10-3, a film thickness measuring instrument 10-4, and a pusher 10-5. The second polishing apparatus (polishing unit) 11 has a polishing table 11-1, a top ring 11-2, a top ring head 11-3, a film thickness measuring instrument 11-4, and a pusher 11-5.

A cassette 1-1 accommodating the semiconductor substrates W, in which a via hole 103 and a trench 104 for interconnect are formed, and a seed layer 107 is formed thereon as shown in FIG. 1A, is placed on a loading port of the loading and unloading section 1. The first robot 3 takes out the semiconductor substrate W from the cassette 1-1, and carries the semiconductor substrate W into the plated Cu film forming unit 2 where a plated Cu film 106 is formed. At this time, the film thickness of the seed layer 107 is measured with the before-plating and after-plating film thickness measuring instrument 12. The plated Cu film 106 is formed by carrying out hydrophilic treatment of the face of the semiconductor substrate W, and then Cu plating. After formation of the plated Cu film 106, rinsing or cleaning of the semiconductor substrate W is carried out in the plated Cu film forming unit 2. If there is time to spare, drying of the semiconductor substrate W may be performed. Constitution examples and operations of the plated Cu film forming unit 2 will be described in detail later on.

When the semiconductor substrate W is taken out from the

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plated Cu film forming unit 2 by the first robot 3, the film thickness of the plated Cu film 106 is measured with the before-plating and after-plating film thickness measuring instrument 12. The method of measurement is the same as for the seed layer 107. The results of its measurement are recorded into a recording device (not shown) as record data on the semiconductor substrate, and are used for judgment of an abnormality of the plated Cu film forming unit 2. After measurement of the film thickness, the first robot 3 transfers the semiconductor substrate W to the reversing machine 5, and the reversing machine 5 reverses the semiconductor substrate W (the surface on which the plated Cu film 106 has been formed faces downward). The first polishing apparatus 10 and the second polishing apparatus 11 perform polishing in a serial mode and a parallel mode. Next, polishing in the serial mode and the parallel mode will be described.

[Serial mode polishing]

In the serial mode polishing, a primary polishing is performed by the polishing apparatus 10, and a secondary polishing is performed by the polishing apparatus 11. The second robot 8 picks up the semiconductor substrate W on the reversing machine 5, and places the semiconductor substrate W on the pusher 10-5 of the polishing apparatus 10. The top ring 10-2 attracts the semiconductor substrate W on the pusher 10-5 by suction, and brings the surface of the plated Cu film 106 of the semiconductor substrate W into contact with a polishing surface 10-1a of the polishing table 10-1 under pressure to perform a primary polishing. With the primary polishing, the plated Cu film 106 is basically polished. The polishing surface 10-1a of the polishing table 10-1 is composed

of foamed polyurethane such as IC1000, or a material having abrasive grains fixed thereto or impregnated therein. Upon relative movements of the polishing surface 10-1a and the semiconductor substrate W, the plated Cu film 106 is polished.

Silica, alumina, ceria, on the like is used as abrasive grains for performing polishing of the plated Cu film 106, or as a slurry ejected from a slurry nozzle 10-6. A mainly acidic material for oxidizing Cu, such as hydrogen peroxide, is used as an oxidizing agent. A temperature controlled fluid piping 28 for passing a liquid whose temperature is adjusted to a predetermined value is connected to the interior of the polishing table 10-1 in order to maintain the temperature of the polishing table 10-1 at a predetermined value. A temperature regulator 10-7 is provided on the slurry nozzle 10-6 in order to maintain the temperature of the slurry at a predetermined value. Water or the like used for dressing is also controlled in temperature, although this is not shown. In this manner, temperature of the polishing table 10-1, the temperature of the slurry, and the temperature of water or the like used for dressing are maintained at predetermined values, whereby the chemical reaction rate is kept constant. Particularly for the polishing table 10-1, ceramics with high thermal conductivity, such as alumina or SiC, are used.

An eddy current film thickness measuring instrument 10-8 or an optical film thickness measuring instrument 10-9 provided in the polishing table 10-1 is used for detection of an end point of the primary polishing. Film thickness measurement of the plated Cu film 106, or surface detection of the barrier layer 5 is performed, and when the film thickness of the plated Cu film 106 reaches zero

or when the surface of the barrier layer 5 is detected, polishing is judged to have reached its end point.

After completion of polishing of the plated Cu film 106, the semiconductor substrate W is returned onto the pusher 10-5 by the top ring 10-2. The second robot 8 picks up the semiconductor substrate W, and introduces it into the first cleaning machine 9. At this time, a chemical liquid may be ejected toward the face and backside of the semiconductor substrate W on the pusher 10-5 to remove particles therefrom or cause particles to be difficult to adhere thereto.

FIG. 4 is a schematic view showing the first cleaning machine. In the first cleaning machine 9, the face and the backside of the semiconductor substrate W are scrubbed with PVA sponge rolls 9-2, 9-2. As cleaning water ejected from nozzles 9-4, pure water is mainly used, but there may be used a surface active agent, or a chelating agent, or a mixture of both which has been adjusted in pH and conformed to the zeta potential of copper oxide. The nozzle 9-4 may also be provided with an ultrasonic vibration element 9-3 for applying ultrasonic vibrations to the cleaning water to be ejected. The reference numeral 9-1 is a rotating roller for rotating the semiconductor substrate W in a horizontal plane.

After completion of cleaning in the first cleaning machine 9, the second robot 8 picks up the semiconductor substrate W, and places the semiconductor substrate W on the pusher 11-5 of the second polishing apparatus 11. The top ring 11-2 attracts the semiconductor substrate W on the pusher 11-5 by suction, and brings the surface of the semiconductor substrate W, which has the barrier layer 105 formed thereon, into contact with a polishing surface

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of the polishing table 11-1 under pressure to perform the secondary polishing. The constitution of the polishing table 11-1 and the top ring 11-2 is the same as the constitution shown in FIG. 3. With this secondary polishing, the barrier layer 105 is polished. However, there may be a case in which a Cu film and an oxide film left after the primary polishing are also polished.

A polishing surface 11-1a of the polishing table 11-1 is composed of foamed polyurethane such as IC1000, or a material having abrasive grains fixed thereto or impregnated therein. Upon relative movements of the polishing surface 11-1a and the semiconductor substrate W, polishing is carried out. At this time, silica, alumina, ceria, on the like is used as abrasive grains or a slurry. A chemical liquid is adjusted depending on the type of the film to be polished.

Detection of an end point of the secondary polishing is performed by measuring the film thickness of the barrier layer 105 mainly with the use of the optical film thickness measuring instrument 10-9 shown in FIG. 3, and detecting the film thickness which has become zero, or the surface of an insulating film 102 comprising SiO_2. Furthermore, a film thickness measuring instrument with an image processing function is used as the film thickness measuring instrument 11-4 provided near the polishing table 11-1. By use of this measuring instrument, measurement of the oxide film is made, the results are stored as processing records of the semiconductor substrate W, and used for judging whether the semiconductor substrate W in which secondary polishing has been finished can be transferred to a subsequent step or not. If the end point of the secondary polishing is not reached, repolishing

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is performed. If over-polishing has been performed beyond a prescribed value due to any abnormality, then the semiconductor substrate processing apparatus is stopped to avoid next polishing so that defective products will not increase.

After completion of the secondary polishing, the semiconductor substrate W is moved to the pusher 11-5 by the top ring 11-2. The second robot 8 picks up the semiconductor substrate W on the pusher 11-5. At this time, a chemical liquid may be ejected toward the face and backside of the semiconductor substrate W on the pusher 11-5 to remove particles therefrom or cause particles to be difficult to adhere thereto.

The second robot 8 carries the semiconductor substrate W into the second cleaning machine 7 where cleaning of the semiconductor substrate W is performed. The constitution of the second cleaning machine 7 is also the same as the constitution of the first cleaning machine 9 shown in FIG. 4. The face of the semiconductor substrate W is scrubbed with the PVA sponge rolls 9-2 using a cleaning liquid comprising pure water to which a surface active agent, a chelating agent, or a pH regulating agent is added. A strong chemical liquid such as DHF is ejected from a nozzle 9-5 toward the backside of the semiconductor substrate W to perform etching of the diffused Cu thereon. If there is no problem of diffusion, scrubbing cleaning is performed with the PVA sponge rolls 9-2 using the same chemical liquid as that used for the face.

After completion of the above cleaning, the second robot 8 picks up the semiconductor substrate W and transfers it to the reversing machine 6, and the reversing machine 6 reverses the semiconductor substrate W. The semiconductor substrate W which

has been reversed is picked up by the first robot 3, and transferred to the third cleaning machine 4. In the third cleaning machine 4, megasonic water excited by ultrasonic vibrations is ejected toward the face of the semiconductor substrate W to clean the semiconductor substrate W. At this time, the face of the semiconductor substrate W may be cleaned with a known pencil type sponge using a cleaning liquid comprising pure water to which a surface active agent, a chelating agent, or a pH regulating agent is added. Thereafter, the semiconductor substrate W is dried by spin-drying.

As described above, if the film thickness has been measured with the film thickness measuring instrument 11-4 provided near the polishing table 11-1, then the semiconductor substrate W is not subjected to further process and is accommodated into the cassette placed on the unloading port of the loading and unloading section 1.

When multilayer film measurement is to be made, measurement in a dry state needs to be performed. Thus, the semiconductor substrate W is once introduced into the film thickness measuring instrument 13 for measurement of each film thickness. In the film thickness measuring instrument 13, the results are stored as processing records of the semiconductor substrate W, or a judgment as to whether the semiconductor substrate W can be brought to a next step or not is made. If the end point of polishing is not reached, feedback is given for the semiconductor substrate W to be processed subsequently. If over-polishing has been performed beyond a prescribed value due to any abnormality, the apparatus is stopped to avoid next polishing so that defective products will

not increase.

[Parallel mode polishing]

In the parallel mode polishing, the semiconductor substrates W having the plated Cu film 106 formed by the plated Cu film forming unit 2 are polished in parallel by the polishing apparatuses 10, 11. The second robot 8 picks up the semiconductor substrate W which has been reversed by the reversing machine 5 as stated above, and places the semiconductor substrate W on the pusher 10-5 or 11-5. The top ring 10-2 or 11-2 attracts the semiconductor substrate W by suction, and brings the surface of the plated Cu film 106 of the semiconductor substrate W into contact with the polishing surface of the polishing table 10-1 or 11-1 under pressure to perform a primary polishing. The polishing surface 10-1a or 11-1a of the polishing table 10-1 or 11-1 is composed of foamed polyurethane such as IC1000, or a material having abrasive grains fixed thereto or impregnated therein, as stated above. Upon relative movements of the polishing surface and the semiconductor substrate W, polishing is performed.

Silica, alumina, ceria, on the like is used as abrasive grains or a slurry. A mainly acidic material for oxidizing Cu, such as hydrogen peroxide, is used as an oxidizing agent. The polishing tables 10-1 and 11-1, and the slurry or water or the like used for dressing are controlled in temperature as stated above to keep the chemical reaction rate constant. Particularly for the polishing tables 10-1 and 11-1, ceramics with high thermal conductivity, such as alumina or SiC, are used.

Polishing in the polishing table 10-1 or 11-1 is performed by a plurality of steps. In the first step, the plated Cu film

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106 is polished. A main purpose of this polishing is the removal of the difference in level on the surface of the plated Cu film 106, and a slurry having excellent level difference characteristics is used. For example, a slurry capable of reducing an initial level difference of 700 nm in a 100 μm line to 20 nm or less is used. At this time, as the second step, the pressing load for pressing the semiconductor substrate W is made a half or less of that in the first step, and the polishing conditions for improving the level difference characteristics are added. For detection of the end point in the second step, the eddy current type measuring machine 10-8 shown in FIG. 3 is used when 500 nm of the plated Cu film 106 is to be left. In the case where 500 nm or less is to be left or polishing is to be performed up to the surface of the barrier layer 105, an optical film thickness measuring instrument 10-9 is used.

After polishing of the Cu layers, i.e. the plated Cu film 106 and the seed layer 107, is completed, polishing of the barrier layer 105 is performed. If the barrier layer 105 cannot be polished usually with the initially used slurry, its composition needs to be changed. Thus, when the second step is completed, the slurry, which has remained on the polishing surface of the polishing table 10-1 or 11-1 and has been used in the first and second steps, is removed by a water polish, a water jet, an atomizer having a mixture of pure water and a gas, or a dresser. Then, the procedure goes to the next step.

FIG. 5 is a view showing the constitution of a cleaning mechanism for cleaning the polishing surface 10-1a of the polishing table 10-1. As illustrated, a plurality of (four in the drawing)

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mixing nozzles 10-11a to 10-11d for mixing pure water and a nitrogen gas and ejecting the mixture are disposed above the polishing table 10-1. Each of the mixing nozzles 10-11a to 10-11d is supplied with a nitrogen gas whose pressure has been controlled by a regulator 16 from a nitrogen gas supply source 14 through an air operator valve 18, and is also supplied with pure water whose pressure has been controlled by a regulator 17 from a pure water supply source 15 through an air operator valve 19.

The mixed gas and liquid undergo changes in parameters, such as the pressure and temperature of the liquid and/or gas and the nozzle shape, by the nozzles. The liquid to be supplied is transformed by nozzle jetting as follows: ① formation of liquid fine particles, ② formation of solid fine particles upon solidification of the liquid, ③ gasification of the liquid upon evaporation (hereinafter,①, ②, ③ are called atomization). A mixture of a liquid-based component and a gas component is jetted, with predetermined directional properties, toward the polishing surface of the polishing table 10-1.

When the polishing surface 10-1a is to be regenerated (dressed) upon relative movements of the polishing surface 10-1a and the dresser 10-10, a mixed fluid of pure water and a nitrogen gas is ejected from the mixing nozzles 10-11a to 11-11d toward the polishing surface 10-1a to clean it. The pressure of the nitrogen gas and the pressure of pure water can be set independently. In the present embodiment, manually driven regulators are used along with a pure water line and a nitrogen line, but regulators whose setting pressures can be changed based on external signals may be used. As a result of cleaning of the polishing surface 10-1a using

the above-described cleaning mechanism, the slurry remaining on the polishing surface in the first polishing step and the second polishing step could be removed by performing cleaning for 5 to 20 seconds. A cleaning mechanism of the same constitution as that shown in FIG. 5 is provided for cleaning the polishing surface 11-1a of the polishing table 11-1, although this is not shown.

As the abrasive grains used in the slurry for polishing of the barrier layer 105 in the third step, it is desirable to use the same abrasive grains as those for polishing of the plated Cu film 106. Moreover, the pH value of the chemical liquid is either on the acid side or on the alkali side, and the preferable conditions are to prevent formation of a mixture on the polishing surface. In both cases, the same particles of silica were used, and both of the chemical liquid with alkalinity and the chemical liquid with acidity, as the pH value of the chemical liquid, obtained good results.

For detection of the end point in the third step, the optical film thickness measuring instrument 10-9 shown in FIG. 3 is used to detect mainly the film thickness of the SiO_2 oxide film and the remainder of the barrier layer 105 and send signals. Furthermore, a film thickness measuring instrument with an image processing function is used as the film thickness measuring instrument 10-4 or 11-4 which is provided near the polishing tables 10-1 and 11-1. By using of this measuring instrument, measurement of the oxide film is made, the results are stored as processing records of the semiconductor substrates W, and used for judging whether the semiconductor substrate W can be transferred to a subsequent step or not. If the end point of polishing in the third step is not

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reached, repolishing is performed. If over-polishing has been performed beyond a prescribed value owing to any abnormality, the semiconductor substrate processing apparatus is stopped to avoid next polishing so that defective products will not increase.

After completion of the third step, the semiconductor substrate W is moved to the pusher 10-5 or 11-5 by the top ring 10-2 or 11-2, and placed on the pusher 10-5 or 11-5. The second robot 8 picks up the semiconductor substrate W on the pusher 10-5 or 11-5. At this time, a chemical liquid may be ejected toward the face and backside of the semiconductor substrate W on the pusher 10-5 or 11-5 to remove particles therefrom or cause particles to be difficult to adhere thereto.

The second robot 8 carries the semiconductor substrate W into the second cleaning machine 7 or the first cleaning machine 9 where cleaning of the semiconductor substrate W is performed. The face of the semiconductor substrate W is scrubbed with PVA sponge rolls using a cleaning liquid comprising pure water to which a surface active agent, a chelating agent, or a pH regulating agent is added. A strong chemical liquid such as DHF is ejected from a nozzle 3-5 toward the backside of the semiconductor substrate W to perform etching of the diffused Cu thereon. If there is no problem of diffusion, scrubbing cleaning is performed with PVA sponge rolls using the same chemical liquid as that for the face.

After completion of the above cleaning, the second robot 8 picks up the semiconductor substrate W and transfers it to the reversing machine 6, and the reversing machine 6 reverses the semiconductor substrate W. The semiconductor substrate W which has been reversed is picked up by the first robot 3, and transferred

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to the third cleaning machine 4. In the third cleaning machine 4, megasonic water excited by ultrasonic vibrations is ejected toward the face of the semiconductor substrate W to perform cleaning. At this time, the face may be cleaned with a known pencil type sponge using a cleaning liquid comprising pure water to which a surface active agent, a chelating agent, or a pH regulating agent is added. After cleaning, the semiconductor substrate W is dried by spin-drying, and then the semiconductor substrate W is picked up by the first robot 3.

If the film thickness has been measured with the film thickness measuring instrument 10-4 or 11-4 provided near the polishing table 10-1 or 11-1 as described above, then the semiconductor substrate W is not subjected to no further process and is accommodated into the cassette 1-1 placed on the unloading port of the loading and unloading section 1.

When multilayer film measurement is to be made, measurement in a dry state needs to be performed. Thus, the semiconductor substrate W is once introduced into the film thickness measuring instrument 13 for measurement of each film thickness. In the film thickness measuring instrument 13, the results are stored as processing records of the semiconductor substrate W, or a judgment as to whether the semiconductor substrate W can be transferred to a next step or not is made. If the end point of polishing is not reached, feedback is given for the semiconductor substrate W to be processed subsequently. If over-polishing has been performed beyond a prescribed value owing to any abnormality, the apparatus is stopped to avoid next polishing so that defective products will not increase.

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FIGS. 6A to 6C are views showing a constitution example of the first robot 3 and the dry state film thickness measuring instrument 13 provided on the hand of the robot. FIG. 6A is a view showing the appearance of the first robot, and FIGS. 6B and 6C are a plan view and a sectional view of the robot hand, respectively. As illustrated, the first robot 3 has two hands 3-1, 3-1 at upper and lower sides, and the hands 3-1, 3-1 are attached to front ends of arms 3-2, 3-2, respectively, so as to be swingably movable. The hands 3-1, 3-1 can scoop up the semiconductor substrate W (drop the semiconductor substrate W into the recesse) and transfer it to a predetermined location.

A plurality of (four in the drawing) eddy current sensors 13a constituting the dry state film thickness measuring instrument 13 are provided in a recessed surface of the hand 3-1 for the semiconductor substrate W, and can measure the film thickness of the semiconductor substrate W placed thereon.

FIGS. 7 to 10 and FIG. 45 are views showing a constitution example of the plated Cu film forming unit 2. FIG. 7 is a view showing a plan constitution of the plated Cu film forming unit, FIG. 8 is a sectional view taken along line A-A of FIG. 7, FIG. 9 is an enlarged sectional view of a substrate holding portion and a cathode portion, FIG. 10 is a sectional view of an electrode arm portion, and FIG. 45 is a plan view of a state in which a housing has been removed from the electrode arm portion shown in FIG. 10. The plated Cu film forming unit 2, as shown in FIG. 7, is provided with a substrate treatment section 2-1 for performing plating treatment and its attendant treatment, and a plating liquid tray 2-2 for storing a plating liquid is disposed adjacent to the

substrate treatment section 2-1. There is also provided an electrode arm portion 2-6 having an electrode portion 2-5 which is held at the front end of an arm 2-4 swingable about a rotating shaft 2-3 and which is swung between the substrate treatment section 2-1 and the plating liquid tray 2-2.

Furthermore, a precoating and recovery arm 2-7, and fixed nozzles 2-8 for ejecting pure water or a chemical liquid such as ion water, and further a gas or the like toward a semiconductor substrate are disposed laterally of the substrate treatment section 2-1. In this case, three of the fixed nozzles 2-8 are disposed, and one of them is used for supplying pure water. The substrate treatment section 2-1, as shown in FIGS. 8 and 9, has a substrate holding portion 2-9 for holding a semiconductor substrate W with its surface to be plated facing upward, and a cathode portion 2-10 located above the substrate holding portion 2-9 so as to surround a peripheral portion of the substrate holding portion 2-9. Further, a substantially cylindrical bottomed cup 2-11 surrounding the periphery of the substrate holding portion 2-9 for preventing scatter of various chemical liquids used during treatment is provided so as to be vertically movable by an air cylinder 2-12.

The substrate holding portion 2-9 is adapted to be raised and lowered by the air cylinder 2-12 between a lower substrate transfer position A, an upper plating position B, and a pretreatment and cleaning position C intermediate between these positions. The substrate holding portion 2-9 is also adapted to rotate at an arbitrary acceleration and an arbitrary velocity integrally with the cathode portion 2-10 by a rotating motor 2-14 and a belt 2-15.

A substrate carry-in and carry-out opening (not shown) is provided in confrontation with the substrate transfer position A in a frame side surface of the plated Cu film forming unit 2 facing the first robot 3. When the substrate holding portion 2-9 is raised to the plating position B, a seal member 2-16 and a cathode electrode 2-17 (to be described below) of the cathode portion 2-10 are brought into contact with the peripheral edge portion of the semiconductor substrate W held by the substrate holding portion 2-9. On the other hand, the cup 2-11 has an upper end located below the substrate carry-in and carry-out opening, and when the cup 2-11 ascends, the upper end of the cup 2-11 reaches a position above the cathode portion 2-10, as shown by imaginary lines in FIG. 9.

When the substrate holding portion 2-9 has ascended to the plating position B, the cathode electrode 2-17 is pressed against the peripheral edge portion of the semiconductor substrate W held by the substrate holding portion 2-9 for thereby allowing electric current to pass through the semiconductor substrate W. At the same time, an inner peripheral end portion of the seal member 2-16 is brought into contact with an upper surface of the peripheral edge of the semiconductor substrate W under pressure to seal its contact portion in a watertight manner. As a result, the plating liquid supplied onto the upper surface of the semiconductor substrate W is prevented from seeping from the end portion of the semiconductor substrate W, and the plating liquid is prevented from contaminating the cathode electrode 2-17.

As shown in FIGS. 10 and 45, an electrode portion 2-5 of the electrode arm portion 2-6 has a housing 2-18 at a free end of a swing arm 2-4, a hollow support frame 2-19 surrounding the housing

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2-18, and an anode 2-20 fixed by holding the peripheral edge portion of the anode 2-20 between the housing 2-18 and the support frame 2-19. The anode 2-20 covers an opening portion of the housing 2-18, and a suction chamber 2-21 is formed inside the housing 2-18. A plating liquid introduction pipe 2-28 and a plating liquid discharge pipe (not shown) for introducing and discharging the plating liquid are connected to the suction chamber 2-21. Further, many passage holes 2-20b communicating with regions above and below the anode 2-20 are provided over the entire surface of the anode 2-20.

In this embodiment, a plating liquid impregnated material 2-22 comprising a water retaining material and covering the entire surface of the anode 2-20 is attached to the lower surface of the anode 2-20. The plating liquid impregnated material 2-22 is impregnated with the plating liquid to wet the surface of the anode 2-20, thereby preventing a black film from falling onto the plated surface of the substrate, and simultaneously facilitating escape of air to the outside when the plating liquid is poured between the surface, to be plated, of the substrate and the anode 2-20. The plating liquid impregnated material 2-22 comprises, for example, a woven fabric, nonwoven fabric, or sponge-like structure comprising at least one material of polyethylene, polypropylene, polyester, polyvinyl chloride, Teflon, polyvinyl alcohol, polyurethane, and derivatives of these materials, or comprises a porous ceramics.

Attachment of the plating liquid impregnated material 2-22 to the anode 2-20 is performed in the following manner: That is, many fixing pins 2-25 each having a head portion at the lower

end are arranged such that the head portion is provided in the plating liquid impregnated material 2-22 so as not to be releasable upward and a shaft portion of the fixing pin pierces the interior of the anode 2-20, and the fixing pins 2-25 are urged upward by U-shaped leaf springs 2-26, whereby the plating liquid impregnated material 2-22 is brought in close contact with the lower surface of the anode 2-20 by the resilient force of the leaf springs 2-26 and is attached to the anode 2-20. With this arrangement, even when the thickness of the anode 2-20 gradually decreases with the progress of plating, the plating liquid impregnated material 2-22 can be reliably brought in close contact with the lower surface of the anode 2-20. Thus, it can be prevented that air enters between the lower surface of the anode 2-20 and the plating liquid impregnated material 2-22 to cause poor plating.

Incidentally, cylindrical pins made of PVC (polyvinyl chloride) or PET (polyethylene terephthalate) and having a diameter of, for example, about 2 mm may be arranged from the upper surface side of the anode so as to pierce the anode, and an adhesive may be applied to the front end surface of each of the pins projecting from the lower surface of the anode to fix the anode to the plating liquid impregnated material. The anode and the plating liquid impregnated material may be used in contact with each other, but it is also possible to provide a gap between the anode and the plating liquid impregnated material, and perform plating treatment while holding the plating liquid in the gap. This gap is selected from a range of 20 mm or less, but is selected from a range of preferably 0.1 to 10 mm, and more preferably 1 to 7 mm. Particularly, when a soluble anode is used, the anode is

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dissolved from its lower portion. Thus, as time passes, the gap between the anode and the plating liquid impregnated material enlarges and forms a gap in the range of 0 to about 20 mm.

The electrode portion 2-5 descends to such a degree that when the substrate holding portion 2-9 is located at the plating position B (see FIG. 9), the gap between the substrate W held by the substrate holding portion 2-9 and the plating liquid impregnated material 2-22 reaches about 0.1 to 10 mm, preferably 0.3 to 3 mm, and more preferably about 0.5 to 1 mm. In this state, the plating liquid is supplied from a plating liquid supply pipe to be filled between the upper surface (surface to be plated) of the substrate W and the anode 2-20 while the plating liquid impregnated material 2-22 is impregnated with the plating liquid. Thus, the surface of the substrate W is plated.

The semiconductor substrate W to be plated is carried into the substrate holding portion 2-9 located at the substrate transfer position A by the hand 3-1 of the first robot 3 (see FIG. 6A), and placed on the substrate holding portion 2-9. Then, the cup 2-11 is raised, and the substrate holding portion 2-9 is simultaneously raised to the pretreatment and cleaning position C. In this state, the precoating and recovery arm 2-7 located at a retreat position is moved to a position opposite to the semiconductor substrate W, and a precoating liquid comprising, for example, a surface active agent is supplied intermittently toward the surface, to be plated, of the semiconductor substrate W from a precoating nozzle provided at the front end of the precoating and recovery arm 2-7. At this time, the substrate holding portion 2-9 is rotating, and hence the precoating liquid spreads over the

entire surface of the semiconductor substrate W. Then, the precoating and recovery arm 2-7 is returned to the retreat position, and the rotational speed of the substrate holding portion 2-9 is increased to remove the precoating liquid on the surface, to be plated, of the semiconductor substrate W by the centrifugal force for thereby drying the surface.

Then, the electrode arm portion 2-6 is swung in a horizontal direction to bring the electrode portion 2-5 from a position above the plating liquid tray 2-2 to a position above a plating position. At this position, the electrode portion 2-5 is lowered toward the cathode portion 2-10. When lowering of the electrode portion 2-5 is completed, a plating voltage is applied to the anode 2-20 and the cathode portion 2-10, and the plating liquid is supplied to the interior of the electrode portion 2-5 to supply the plating liquid to the plating liquid impregnated material 2-22 through the plating liquid supply ports piercing the anode 2-20. At this time, the plating liquid impregnated material 2-22 does not contact the surface, to be plated, of the semiconductor substrate W, but approaches it at a distance of about 0.1 to 10 mm, preferably 0.3 to 3 mm, and more preferably about 0.5 to 1 mm.

When the supply of the plating liquid continues, the plating liquid containing Cu ions, which has seeped out of the plating liquid impregnated material 2-22, is filled into the gap between the plating liquid impregnated material 2-22 and the surface, to be plated, of the semiconductor substrate W to apply Cu plating to the surface of the semiconductor substrate W. At this time, the substrate holding portion 2-9 may be rotated at a low speed.

When the plating treatment is completed, the electrode arm

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portion 2-6 is raised and then swung to return the electrode portion 2-5 to the position above the plating liquid tray 2-2 and to lower the electrode portion 2-5 to the ordinary position. Then, the precoating and recovery arm 2-7 is moved from the retreat position to the position opposite to the semiconductor substrate W, and lowered to recover the remainder of the plating liquid on the semiconductor substrate W by a plating liquid recovery nozzle (not shown). After recovery of the remainder of the plating liquid is completed, the precoating and recovery arm 2-7 is returned to the retreat position, and pure water is supplied toward the central portion of the semiconductor substrate W. At the same time, the substrate holding portion 2-9 is rotated at an increased speed to replace the plating liquid on the face of the semiconductor substrate W with pure water.

After completion of the above rinsing, the substrate holding portion 2-9 is lowered from the plating position B to the treatment and cleaning position C. Then, while pure water is supplied from the fixed nozzles 2-8, the substrate holding portion 2-9 and the cathode portion 2-10 are rotated to perform washing with water. At this time, the seal member 2-16 and the cathode electrode 2-17 can also be cleaned, simultaneously with the semiconductor substrate W, by means of pure water directly supplied to the cathode 2-10, or pure water scattered from the surface of the semiconductor substrate W.

After washing with water is completed, supply of pure water from the fixed nozzles 2-8 is stopped, and the rotational speed of the substrate holding portion 2-9 and the cathode portion 2-10 is further increased to remove pure water on the face of the

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semiconductor substrate W by centrifugal force and to dry the face of the semiconductor substrate W. The seal member 2-16 and the cathode electrode 2-17 are also dried at the same time. Upon completion of the drying, the rotation of the substrate holding portion 2-9 and the cathode portion 2-10 is stopped, and the substrate holding portion 2-9 is lowered to the substrate transfer position A.

FIGS. 11 and 12 show the anode 2-20 and the plating liquid impregnated material 2-22 according to another embodiment of the present invention. That is, in this embodiment, the plating liquid impregnated material 2-22 is composed of porous ceramics such as alumina, SiC, mullite, zirconia, titania or cordierite, or a hard porous material such as a sintered compact of polypropylene or polyethylene, or a composite material comprising these materials. In case of the alumina-based ceramics, for example, the ceramics with a pore diameter of 30 to 200 μm, a porosity of 20 to 95%, and a thickness of about 5 to 20 mm, preferably 8 to 15 mm, are used.

The plating liquid impregnated material 2-22 has a flange portion 2-22a provided at the upper portion thereof, and is fixed by holding this flange portion 2-22a between the housing 2-18 and the support frame 2-19 (see FIG. 10). The anode 2-20 is placed and held on the upper surface of the plating liquid impregnated material 2-22. In this embodiment, the anodes of various shapes, such as porous ones or mesh-like ones may be placed.

As described above, in the case where the plating liquid impregnated material 2-22 is composed of a porous material, the electrical resistance of the interior of the plating liquid impregnated material 2-22 can be increased by the plating liquid

which has complicatedly entered the plating liquid impregnated material 2-22. Thus, the thickness of the plated film can be uniformized, and the generation of particles can be prevented. That is, the plating liquid impregnated material 2-22 is a kind of high-resistance member comprising porous ceramics, and is thus preferable for achieving uniformity of the plated film thickness. Furthermore, the anode 2-20 is placed and held on the plating liquid impregnated material 2-22. Thus, even when the side of the lower surface of the anode 2-20 which is in contact with the plating liquid impregnated material 2-22 is dissolved with the progress of plating, the distance between the lower surface of the anode 2-20 and the substrate W can be kept constant by the own weight of the anode 2-20 without the use of a jig for fixing the anode 2-20, and air accumulation caused by air entering therein can be prevented. Incidentally, a gap may be provided between the anode and the plating liquid impregnated material, and plating treatment may be performed with the plating liquid being held in this gap. This gap is selected from the range of 20 mm or less, preferably 0.1 to 10 mm, and more preferably 1 to 7 mm.

FIG. 51 is an electrical equivalent circuit diagram of the apparatus shown in FIGS. 11 and 12.

When a predetermined voltage is applied by a plating power source 2-37 between the anode 2-20 (anodic electrode) submerged in the plating liquid and the conductive layer 1a (cathodic electrode) of the substrate W to form a plated film on the surface of the conductive layer 1a, the following resistance components exist in this circuit:

R1: Power source wire resistance between power source and

anode, and various contact resistances

R2: Polarization resistance at anode

R3: Plating liquid resistance

R4: Polarization resistance at cathode (plated surface)

Rp: Resistance value of high resistance structure

R5: Resistance of conductive layer

R6: Power source wire resistance between cathode potential lead-in contact and power source, and various contact resistances

The resistance value Rp of a high resistance structure, which is the plating liquid impregnated material 2-22, is 0.01 Ω or more, preferably 0.01 to 2 Ω, more preferably 0.03 to 1 Ω, and even more preferably 0.05 to 0.5 Ω, for example, in the case of a 200 mm wafer. The resistance value of this high resistance structure is measured by the following procedure: First, in the plating apparatus, a direct current (I) of a predetermined value is flowed between both electrodes comprising the anode 2-20 and the substrate W spaced by a predetermined distance to perform plating, and the voltage (V1) of the direct current power source at this time is measured. Then, in the same plating apparatus, the high resistance structure of a predetermined thickness is placed between both electrodes, and a direct current (I) of the same value is flowed to perform plating. At this time, the voltage (V2) of the direct current power source is measured. With this method, the resistance value Rp of the high resistance structure can be calculated from Rp = (V2 - V1)/I. In this case, the purity of copper constituting the anode is preferably 99.99% or more. The distance between the two electrode plates comprising the anode plate and the substrate is preferably in the range of 5 to 25 mm in the case of the substrate

having a diameter of 200 mm, and is preferably in the range of 15 to 75 mm in the case of the substrate having a diameter of 300 mm. The resistance R5 of the conductive layer 1a on the substrate W can be determined by measuring the resistance value between the outer periphery and the center of the substrate with the use of a tester, or calculated from the specific resistance of the material of the conductive layer 1a and the thickness of the conductive layer 1a.

In the embodiment shown in FIGS. 11 and 12, a plating liquid introduction pipe 2-28 of a straight-line shape, which has a plating liquid introduction passage 2-28a therein and extends in a diametrical direction, is installed on the upper surface of the anode 2-20. In the anode 2-20, plating liquid pouring holes 2-20a are provided at positions aligned with plating liquid introduction holes 2-28b provided in the plating liquid introduction pipe 2-28. Many passage holes 2-20b are also provided in the anode 2-20.

At positions approximately corresponding to the plating liquid pouring holes 2-20a of the anode 2-20, the plating liquid reaches the upper surface (surface to be plated) of the substrate W from the lower surface of the plating liquid impregnated material 2-22, thereby forming plating liquid columns 2-30 which crosslink the plating liquid impregnated material 2-22 and the surface, to be plated, of the substrate W. By continuing the supply of the plating liquid, the plating liquid columns 2-30 are gradually grown, or connected to each other. Then, a flow of the plating liquid Q, which advances in a direction perpendicular to the plating liquid introduction pipe 2-28 and spreads over the entire surface of the surface, to be plated, of the substrate W, occurs as shown in FIG.

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46.

As a result, air bubbles B entrained by this flow of the plating liquid Q are pushed outward, and a front line Q1 of the flow of the plating liquid Q is a nearly straight line, so that the plating liquid Q does not enclose air. Thus, the air bubbles are prevented from remaining in the plating liquid filled between the plating liquid impregnated material 2-22 and the surface, to be plated, of the substrate W.

Here, as shown in FIG. 47A, the plating liquid introduction pipe 2-28 which has blade portions extending cruciformly in directions perpendicular to each other and which has plating liquid introduction holes 2-28b at predetermined positions along the longitudinal direction of each blade portion may be used, and the anode (not shown) which has plating liquid pouring holes 2-20a at positions corresponding to the plating liquid introduction holes 2-28b may be used. In this case, in the same manner as stated above, plating liquid columns crosslinking the plating liquid impregnated material and the surface, to be plated, of the substrate W are formed at positions approximately corresponding to the plating liquid pouring holes 2-20a of the anode. As the supply of the plating liquid continues, the plating liquid columns gradually grow. Then, a flow of the plating liquid Q, which spreads radially in quadrants defined by the plating liquid introduction pipe 2-28, is generated and the plating liquid Q spreads over the entire surface of the surface, to be plated, of the substrate W. As shown in FIG. 47B, a similar flow of the plating liquid Q is generated, when the plating liquid introduction pipe 2-28 is placed in a circumferential manner and plating liquid introduction holes 2-28b are provided at

predetermined positions. The plating liquid introduction holes 2-28b of the plating liquid introduction pipe 2-28 are often provided at equal pitch and with equal diameter, but discharge of the liquid may be controlled by adjusting the pitch of the holes and the diameter of the holes.

According to the embodiment shown in FIGS. 11, 12 and 46, at positions approximately corresponding to the plating liquid pouring holes 2-20a of the anode 2-20, the plating liquid reaches the upper surface (surface to be plated) of the substrate W from the lower surface of the plating liquid impregnated material 2-22, thereby forming the plating liquid columns 2-30 which crosslink the plating liquid impregnated material 2-22 and the surface, to be plated, of the substrate W. At this time, when the plating liquid flows inside the plating liquid impregnated material 2-22, the plating liquid is slightly diffused along its flow direction, thereby alleviating damage to the seed layer 107 (see FIG. 1A) upon arrival of the plating liquid at the substrate W, namely, alleviating the phenomenon of the seed layer due to local application of a jet, and thus contributing to the uniformity of the film thickness during a subsequent plating step.

By providing the distribution of the passage holes 2-20b over the surface so as to be dense in the central portion and sparse in the peripheral portion, the plating liquid spreads uniformly.

As indicated by imaginary lines in FIG. 12, after the plating liquid reaches the upper surface (surface to be plated) of the substrate W from the lower surface of the plating liquid impregnated material 2-22 to form the plating liquid columns 2-30, the substrate W, for example, may be instantaneously raised to bring the plating

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liquid impregnated material 2-22 and the substrate W close to each other instantaneously. Further, it is possible to form the plating liquid columns 2-30 similarly while bending the substrate in a concave form under slight pressure on the edge of the substrate, and then to release the pressure, thereby restoring the substrate to the original shape. With this measure, the plating liquid impregnated material 2-22 and the substrate W may be instantaneously brought close to each other.

When the plating liquid impregnated material 2-22 has a large thickness and a high density (low porosity), for example, resistance becomes large when the plating liquid flows inside the plating liquid impregnated material 2-22. As a result, a predetermined amount of the plating liquid does not flow out of the plating liquid impregnated material 2-22, and binding of the plating liquid columns 2-30 is disturbed. Even if air is dragged at this time, the plating liquid impregnated material 2-22 and the substrate W can be instantaneously brought close to each other. With this measure, a rapid outward flow of the plating liquid can be generated to drive out air bubbles together with the plating liquid, and the supply of the plating liquid between the plating liquid impregnated material 2-22 and the substrate W can be performed in a short time.

Contact between the plating liquid and the seed layer 107 (see FIG. 1A) in a non-energized state induces a decrease in the seed layer 107. Even in an energized state, the failure of the plating liquid to spread on the surface of the substrate W in a short time causes variations in the film thickness at the initial stage of plating, and impairs the uniformity of subsequent plated

film thickness. However, these troubles can be prevented by supplying the plating liquid between the plating liquid impregnated material 2-22 and the substrate W in a short time.

Further, as shown in FIG. 11, the plating liquid may be supplied from the plating liquid pouring holes 2-20a to the plating liquid impregnated material 2-22 during plating treatment to supply the plating liquid between the plating liquid impregnated material 2-22 and the surface, to be plated, of the substrate W. Simultaneously, the plating liquid in the same amount as the amount of the poured plating liquid can be sucked and discharged via the passage holes 2-20b through a plating liquid discharge pipe (not shown) connected to the passage holes 2-20b.

The plating liquid is stirred in this manner during plating treatment, whereby it becomes possible to remove air bubbles which have not been withdrawn during liquid filling, and air bubbles which have occurred during plating treatment after liquid filling.

In the present plating apparatus, the spacing between the surface, to be plated, of the substrate W and the anode 2-20 is small, so that a small amount of the plating liquid to be used is sufficient. However, since the additives and ions in the plating liquid become in limited amounts, in order to perform efficient plating in a short time, it is necessary to distribute the additives and the like uniformly in the plating liquid. In this respect, according to the present embodiment, because the plating liquid is stirred during plating treatment, it is possible to perform plating in such a state that the additives and ions are distributed uniformly. In the present plating apparatus, plating is applied onto the semiconductor substrate W by connecting the semiconductor

substrate W to the cathode and connecting the anode to the positive electrode. By applying a reverse voltage, on the other hand, etching of the plated film provided on the semiconductor substrate W can be carried out. After plating for filling the hole is substantially completed (40 to 400 seconds), a feed voltage is applied for a short time (e.g., 1 to 60 seconds), and then a forward voltage is applied again (50 seconds, 0.5 μ). By applying feed voltage, the action of the additives is suppressed, and formation of a protuberance only on the hole is prevented, so that uniformity of the plated film can be achieved.

FIG. 42 shows another embodiment, and in this embodiment, pipes 2-32 communicating with a plating liquid introduction pipe 2-28 are provided in the plating liquid introduction pipe 2-28 per se, the pipes 2-32 are inserted into plating liquid introduction holes 2-28b of the anode 2-20, and the front ends of the pipes 2-32 are brought into contact with the surface of the plating liquid impregnated material 2-22. That is, in this embodiment, the plating liquid can be supplied to the surface of the plating liquid impregnated material 2-22 without causing the plating liquid to contact the anode 2-20 at all. The plating liquid introduction pipe 2-28 and the pipes 2-32 are integrally formed by a synthetic resin of a material which is not affected at all by the plating liquid. The reference numeral 2-31 denotes a holding member for holding the substrate W.

The plating liquid, which has been directly supplied to the surface of the plating liquid impregnated material 2-22 from the plating liquid introduction pipe 2-28 through the pipes 2-32, reaches the face of the substrate W while the plating liquid is

slightly diffusing in the plating liquid impregnated material 2-22, and the plating liquid forms a plurality of circular plating liquid columns 2-30 between the substrate W and the surface of the plating liquid impregnated material 2-22, and the plural plating liquid columns 2-30 bind to each other on the substrate W, thus filling the face of the substrate W with the plating liquid.

Even when this plating step is repeated, the inner diameter of the front end of the pipe 2-32 does not increase with the passage of time, and hence the ideal plating liquid columns 2-30 do not collapse with the passage of time. Consequently, engulfment of air due to disturbance of binding of the plating liquid columns 2-30 does not take place. Air bubbles are not accumulated between the plating liquid impregnated material 2-22 and the substrate W, and the plated film thickness does not become nonuniform.

FIG. 43 is a view showing a schematic constitution of an electroplating apparatus using another embodiment of the present invention. This electroplating apparatus differs from that in the embodiment shown in FIG. 42 in that instead of forming pipes 2-32 integrally with a plating liquid introduction pipe 2-28, separately prepared pipes 2-33 are inserted into plating liquid introduction holes 2-28b of the anode 2-20. In this case also, the pipes 2-33 are composed of a material which is not affected at all by the plating liquid, and the front ends (lower ends) of the pipes 2-33 are brought into contact with the upper surface of the plating liquid impregnated material 2-22.

Even with this constitution, the plating liquid does not directly contact the anode 2-20 in the same manner as the embodiment shown in FIG. 42. Even when the plating step is performed

repeatedly, the inner diameter of the front end of the pipe 2-33 does not increase with the passage of time. Thus, the plating liquid columns 2-30 supplied from the plating liquid impregnated material 2-22 do not collapse with the passage of time, but can be always kept in the ideal state, and engulfment of air does not occur.

FIG. 44 is a view showing a schematic constitution of an electroplating apparatus using another embodiment of the present invention. This electroplating apparatus differs from that in the embodiment shown in FIG. 42 in that instead of forming pipes 2-32 integrally with a plating liquid introduction pipe 2-28, separately prepared pipes 2-33 are inserted into plating liquid introduction holes 2-28b of the anode 2-20 and electrolytic solution passage portions 2-34 provided in the plating liquid impregnated material 2-22. In this case also, the pipes 2-33 are composed of a material which is not affected at all by the plating liquid.

With this constitution, even when the plating step is performed repeatedly, the inner diameter of the front end of the pipe 2-33 does not increase with the passage of time, and hence the ideal plating liquid columns 2-30 do not collapse with the passage of time. Consequently, engulfment of air due to disturbance of binding of the plating liquid columns 2-30 does not take place, and air bubbles are not accumulated between the plating liquid impregnated material 2-22 and the substrate W, and the plated film thickness does not become nonuniform. At the same time, the pipes 2-33 protrude into the plating liquid impregnated material 2-22, and hence there is a decrease in the resistance when the

plating liquid passes through the plating liquid impregnated material 2-22. Even if the plating liquid impregnated material 2-22 having a large thickness or a high density (low porosity) is used, an appropriate amount of the plating liquid is supplied from predetermined positions of the plating liquid impregnated material 2-22. As a result, engulfment of air due to disturbance of binding of the plating liquid columns 2-30 does not take place, and air bubbles are not accumulated between the plating liquid impregnated material 2-22 and the substrate W, and thus the plated film thickness does not become nonuniform.

FIG. 48 is a cross-sectional view showing a modified example of the embodiment shown in FIG. 42.

In the plating apparatus shown in FIG. 42, the electric field on the surface, to be processed, of the substrate can be controlled by at least one of adjustment of the external form of the plating liquid impregnated material 2-22, adjustment of the internal structure of the plating liquid impregnated material 2-22, and adjustment by mounting of a member with different electric conductivity. In this manner, if the state of the electric field on the surface, to be processed, of the substrate is positively controlled to the desired state, a processed state by electrolytic treatment of the substrate to be processed can be made a processed state with desired distribution on the surface. In case electrolytic treatment is plating treatment, the thickness of a plated film formed on the substrate to be processed can be uniformized, or an arbitrary distribution can be imparted to the thickness of the plated film formed on the substrate to be processed.

The adjustment of the external form shape can be made by adjustment of the thickness of the plating liquid impregnated material 2-22, adjustment of the shape of the plating liquid impregnated material 2-22 on the plane, or the like.

The plating liquid impregnated material 2-22 is composed of a porous substance. Adjustment of the internal structure of the porous substance is performed by adjustment of the pore diameter distribution of the porous substance, adjustment of porosity distribution, adjustment of flexing rate distribution, or adjustment of a combination of materials.

The adjustment by mounting of a member with different electric conductivity is performed by adjusting the shielding area of the plating liquid impregnated material 2-22 with the use of a member with different electric conductivity.

In the embodiment shown in FIG. 48, a band-like insulating member 2-35 is wound around an outer peripheral side surface of a porous ceramic plate (porous substance) 2-22 so as to surround the outer peripheral side surface. As the material of the insulating member 2-35, an extensible material such as fluororubber is used.

A plating liquid, which has been supplied under pressure from a plating liquid introduction pipe 2-28 to the porous ceramic plate (plating liquid impregnated material) 2-22 through plating liquid introduction holes 2-28b of an anode 2-20, permeates the interior of the porous ceramic plate 2-22 to fill the interior of the porous ceramic plate 2-22 with the plating liquid. Then, the plating liquid is discharged from the lower surface of the porous ceramic plate 2-22 to fill a space between the substrate W and the porous

ceramic plate 2-22 with the plating liquid. Introduction of the plating liquid may be performed from a gap between a lip seal 2-16 and an end surface of the porous ceramic plate 2-22. In this case, neither the plating liquid introduction pipe 2-28 nor the plating liquid introduction holes 2-28b of the anode 2-20 are necessary.

When a predetermined voltage is applied between the anode 2-20 and the substrate W to flow a direct current, plating (e.g. copper plating) is applied on the entire surface of the conductive layer of the substrate W. According to the present embodiment, the porous ceramic plate 2-22 is interposed between the anode 2-20 and the substrate W, and hence there is minimal influence due to the difference among the resistance values of the respective portions according to the difference in the distance from contacts 2-17 on the surface of the substrate W as stated above. Consequently, substantially uniform plating (e.g. copper plating) is applied on the entire surface of the conductive layer of the substrate W.

However, portions in the vicinity of the outer peripheral portion close to the contacts 2-17 are still high in current density, and tend to be thicker in plated film thickness than other portions.

In the present embodiment, therefore, an insulating member 2-35 is wound around the outer peripheral side surface of the porous ceramic plate 2-22 to prevent an electric current from concentrating at an area near the outer peripheral portion of the substrate W, as shown by dotted lines in FIG. 48, thereby decreasing the current density at such area and making it nearly equal to the current density directed toward the other portions of the substrate W.

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Here, the following constitution may be adopted in an electrolytic treatment apparatus in which an electrolytic solution is filled between a substrate, to be treated, having contacts which are brought in contact with one of an anode and a cathode, and the other electrode opposite to the substrate to perform electrolytic treatment of the substrate: A high resistance structure having electric conductivity smaller than the electric conductivity of the electrolytic solution is provided in at least part of the electrolytic solution, the high resistance structure has an outer periphery held by a holding member, and a seal member is provided between the high resistance structure and the holding member for preventing the electrolytic solution from leaking from this area and preventing an electric current from flowing.

[Embodiment using seal member]

FIG. 49 is a schematic view of an essential part showing portions in the vicinity of the outer peripheral portion of a porous ceramic plate 2-22 of an electroplating apparatus having the same structure as that shown in FIG. 48. However, the insulating member 2-35 shown in FIG. 48 is not shown in this electroplating apparatus. In this electroplating apparatus, since a gap between a holding member 2-18 and the porous ceramic plate 2-22 is not sealed, a plating liquid flows out of the anode 2-20 through this gap to thus form a passage for an electric current as shown by an arrow. Since this current passage is such a passage that current does not pass through the interior of the porous ceramic plate 2-22, its resistance value is small. Thus, the current density becomes so high that control for decreasing the plated film thickness in the vicinity of the outer peripheral portion of the substrate W may

be impossible.

In this embodiment, therefore, a seal member 2-36 is provided between the porous ceramic plate 2-22 and the holding member 2-18, as shown in FIGS. 50A and 50B. With this arrangement, leakage of the plating liquid from this portion is prevented so that the plated film thickness in the vicinity of the outer peripheral portion of the substrate W can be controlled so as to be small.

The seal member 2-36 in this embodiment has an inverted L-shaped cross section, and is composed of an insulating material, and thus the seal member 2-36 also serves as the insulating member shown in FIG. 48. The seal member 2-36, as its cross section is shown in FIG. 50B, may be constructed by attaching, as separate parts, an annular seal member portion 2-36a for sealing the portion at which the holding member 2-18 and the lower surface of the porous ceramic plate 2-22 are in contact with each other, and an insulating member portion 2-36b exhibiting the same function as the band-like insulating member 2-35 shown in FIG. 48.

The seal member 2-36, needless to say, can be applied to the respective embodiments other than the embodiment in FIG. 48. Specifically, more effective electric field control can be performed by jointly using the seal member 2-36 for preventing leakage of the plating liquid from a portion between the outer peripheral side surface of the high resistance structure 4 and the holding member 2-18, and electric field control means according to other various embodiments.

FIG. 13 is a view showing another plan layout constitution of the substrate processing apparatus according to the present invention. In FIG. 13, portions denoted by the same reference

numerals as those in FIG. 2 show the same or corresponding portions. The same is true of FIGS. 14 and 15. In the present substrate polishing apparatus, a pusher indexer 25 is disposed close to a first polishing apparatus 10 and a second polishing apparatus 11, substrate placing tables 21, 22 are disposed close to a third cleaning machine 4 and a plated Cu film forming unit 2, respectively, and a robot 23 (hereinafter referred to as second robot 23) is disposed close to a first cleaning machine 9 and the third cleaning machine 4. Further, a robot 24 (hereinafter referred to as third robot 24) is disposed close to a second cleaning machine 7 and the plated Cu film forming unit 2, and a dry state film thickness measuring instrument 13 is disposed close to a loading and unloading section 1 and a first robot 2.

In the substrate processing apparatus of the above constitution, the first robot 3 takes out a semiconductor substrate W from a cassette 1-1 placed on the load port of the loading and unloading section 1. After the film thicknesses of a barrier layer 105 and a seed layer 107 are measured with the dry state film thickness measuring instrument 13, the first robot 3 places the semiconductor substrate W on the substrate placing table 21. In the case where the dry state film thickness measuring instrument 13 is provided on the hand 3-1 of the first robot 3 as shown in FIGS. 6B and 6C, the film thicknesses are measured thereon, and the substrate is placed on the substrate placing table 21. The second robot 23 transfers the semiconductor substrate W on the substrate placing table 21 to the plated Cu film forming unit 2 in which a plated Cu film 106 is formed. After formation of the plated Cu film 106, the film thickness of the plated Cu film 106

is measured with a before-plating and after-plating film thickness measuring instrument 12. Then, the second robot 23 transfers the semiconductor substrate W to the pusher indexer 25 and loads it thereon.

[Serial mode]

In the serial mode, a top ring head 10-2 holds the semiconductor substrate W on the pusher indexer 25 by suction, transfers it to a polishing table 10-1, and presses the semiconductor substrate W against a polishing surface on the polishing table 10-1 to perform polishing. Detection of the end point of polishing is performed by the same method as described above. The semiconductor substrate W after completion of polishing is transferred to the pusher indexer 25 by the top ring head 10-2, and loaded thereon. The second robot 23 takes out the semiconductor substrate W, and carries it into the first cleaning machine 9 for cleaning. Then, the semiconductor substrate W is transferred to the pusher indexer 25, and loaded thereon.

A top ring head 11-2 holds the semiconductor substrate W on the pusher indexer 25 by suction, transfers it to a polishing table 11-1, and presses the semiconductor substrate W against a polishing surface on the polishing table 11-1 to perform polishing. Detection of the end point of polishing is performed by the same method as described above. The semiconductor substrate W after completion of polishing is transferred to the pusher indexer 25 by the top ring head 11-2, and loaded thereon. The third robot 24 picks up the semiconductor substrate W, and its film thickness is measured with a film thickness measuring instrument 26. Then, the semiconductor substrate W is carried into the second cleaning

machine 7 for cleaning. Thereafter, the semiconductor substrate W is carried into the third cleaning machine 4, where it is cleaned and then dried by spin-drying. Then, the semiconductor substrate W is picked up by the third robot 24, and placed on the substrate placing table 22.

[Parallel mode]

In the parallel mode, the top ring head 10-2 or 11-2 holds the semiconductor substrate W on the pusher indexer 25 by suction, transfers it to the polishing table 10-1 or 11-1, and presses the semiconductor substrate W against the polishing surface on the polishing table 10-1 or 11-1 to perform polishing. After measurement of the film thickness, the third robot 24 picks up the semiconductor substrate W, and places it on the substrate placing table 22.

The first robot 3 transfers the semiconductor substrate W on the substrate placing table 22 to the dry state film thickness measuring instrument 13. After the film thickness is measured, the semiconductor substrate W is returned to the cassette 1-1 of the loading and unloading section 1.

FIG. 14 is a view showing another plan layout constitution of the substrate processing apparatus according to the present invention. The present substrate processing apparatus is such a substrate processing apparatus which forms a seed layer 107 and a plated Cu film 106 on a semiconductor substrate W having no seed layer 107 formed thereon, and polishes and removes these films to form interconnects. The present substrate processing apparatus differs from the substrate processing apparatus shown in FIG. 2 in that a seed layer forming unit 27 is provided instead of the

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third cleaning machine 4 in FIG. 2.

A cassette 1-1 accommodating the semiconductor substrates W before formation of the seed layer 107 is placed on a load port of a loading and unloading section 1. The semiconductor substrate W before formation of the seed layer 107 is taken out from the cassette 1-1 by a first robot 3, and the seed layer (Cu seed layer) 107 is formed by the seed layer forming unit 27. The seed layer 107 is formed by electroless plating, and after its formation, heat is applied to make the adhesion of the seed layer 107 higher. The film thickness of the seed layer 107 is measured with a before-plating and after-plating film thickness measuring instrument 12.

The semiconductor substrate is taken out by the first robot 3, and the plated Cu film 106 is formed by a plated Cu film forming unit 2. Formation of the plated Cu film 106 is performed by carrying out hydrophilic treatment of the face of the semiconductor substrate W, and then Cu plating. Then, rinsing or cleaning is carried out. If there is some time to spare, drying may be performed. When the semiconductor substrate W is taken out by the first robot 3, the film thickness of the plated Cu film 106 is measured with the before-plating and after-plating film thickness measuring instrument 12. The method of measurement is the same as that of the film thickness measurement of the seed layer 107, and the results of its measurement are recorded as record data on the semiconductor substrate W and are also used for judgment of an abnormality of the plated Cu film forming unit 2. After measurement of the film thickness, the first robot 3 transfers the semiconductor substrate W to a reversing machine 5 in which the

semiconductor substrate W is turned over.

Then, a second robot 8 picks up the semiconductor substrate W from the reversing machine 5, and places it on a pusher 10-5 or 11-5. Then, the top ring 10-2 or 11-2 holds the semiconductor substrate W by suction, transfers it onto a polishing table 10-1 or 11-1, and presses it against a polishing surface on the polishing table 10-1 or 11-1 to perform polishing. This polishing is substantially the same as the treatment in the steps 1 to 3 in the parallel mode polishing by the substrate processing apparatus shown in FIG. 2, and thus its explanations are omitted.

After completion of polishing, the top ring 10-2 or 11-2 returns the semiconductor substrate W to the pusher 10-5 or 11-5. The second robot 8 picks up the semiconductor substrate W, and carries it into a first cleaning machine 9. At this time, a chemical liquid may be ejected toward the face and backside of the semiconductor substrate W on the pusher 10-5 or 11-5 to remove particles therefrom or cause particles to be difficult to adhere thereto.

In the first cleaning machine 9, the face and the backside of the semiconductor substrate W are scrubbed and cleaned. The face of the semiconductor substrate W is scrubbed and cleaned mainly for removal of particles with a PVA roll sponge using cleaning water comprising pure water to which a surface active agent, a chelating agent, or a pH regulator is added. A strong chemical liquid such as DHF is ejected toward the backside of the semiconductor substrate W to etch diffused Cu. If there is no problem of Cu diffusion, the backside of the semiconductor substrate W is scrubbed and cleaned with a PVA roll sponge using the same chemical liquid as

that for the face.

After cleaning, the second robot 8 picks up the semiconductor substrate W, and transfers it to a reversing machine 6 where the semiconductor substrate W is reversed. The semiconductor substrate W is picked up again by the second robot 8, and carried into a second cleaning machine 7 by the second robot 8. In the second cleaning machine 7, megasonic water to which ultrasonic vibrations are applied is ejected toward the face of the semiconductor substrate W to clean the face. At this time, the face may be cleaned with a pencil type sponge using a cleaning liquid comprising pure water to which a surface active agent, a chelating agent, or a pH regulator is added. Thereafter, the semiconductor substrate W is dried by spin-drying.

Then, the second robot 8 picks up the semiconductor substrate W, and transfers it to the reversing machine 6 as it is. The first robot 3 picks up the semiconductor substrate W on the reversing machine 6. In the case where the film thickness has been measured with a film thickness measuring instrument 10-4 or 11-4 provided near the polishing table 10-1 or 11-1 as described above, the semiconductor substrate W is received by the cassette 1-1 placed in the unload port of the loading and unloading section 1. In the case where the film thicknesses of multilayer films are to be measured, measurement in a dry state needs to be performed. Thus, the film thickness is measured once with a dry state film thickness measuring instrument 13. In this case, if the dry state film thickness measuring instrument 13 is provided on the hand 3-1 of the first robot 3 as shown in FIGS. 6B and 6C, the film thickness can be measured on the robot hand. The results of the film

thickness measurement are retained as processing records of the semiconductor substrate W, or a judgment as to whether the semiconductor substrate W can be delivered to a next step or not is made.

FIG. 15 is a view showing another plan layout constitution of the substrate processing apparatus according to the present invention. The present substrate processing apparatus, as is the case with the substrate processing apparatus shown in FIG. 14, is such a substrate processing apparatus which forms a seed layer 107 and a plated Cu film 106 on a semiconductor substrate W having no seed layer 107 formed thereon, and polishes these films to form interconnects.

In the present substrate polishing apparatus, a pusher indexer 25 is disposed close to a first polishing apparatus 10 and a second polishing apparatus 11, substrate placing tables 21, 22 are disposed close to a second cleaning machine 7 and a seed layer forming unit 27, respectively, and a robot 23 (hereinafter referred to as second robot 23) is disposed close to the seed layer forming unit 27 and a plated Cu film forming unit 2. Further, a robot 24 (hereinafter referred to as third robot 24) is disposed close to a first cleaning machine 9 and the second cleaning machine 7, and a dry state film thickness measuring instrument 13 is disposed close to a loading and unloading section 1 and a first robot 2.

The first robot 3 takes out a semiconductor substrate W having a barrier layer 105 thereon from a cassette 1-1 placed on the load port of the loading and unloading section 1, and places it on the substrate placing table 21. Then, the second robot 23 transports the semiconductor substrate W to the seed layer forming

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unit 27 where a seed layer 107 is formed. The seed layer 107 is formed by electroless plating. The second robot 23 enables the semiconductor substrate having the seed layer 107 formed thereon to be measured in thickness of the seed layer 107 by the before-plating and after-plating film thickness measuring instrument 12. After measurement of the film thickness, the semiconductor substrate is carried into the plated Cu film forming unit 2 where a plated Cu film 106 is formed.

After formation of the plated Cu film 106, its film thickness is measured, and the semiconductor substrate is transferred to a pusher indexer 25. A top ring 10-2 or 11-2 holds the semiconductor substrate W on the pusher indexer 25 by suction, and transfers it to a polishing table 10-1 or 11-1 to perform polishing. After polishing, the top ring 10-2 or 11-2 transfers the semiconductor substrate W to a film thickness measuring instrument 10-4 or 11-4 to measure the film thickness. Then, the top ring 10-2 or 11-2 transfers the semiconductor substrate W to the pusher indexer 25, and places it thereon.

Then, the third robot 24 picks up the semiconductor substrate W from the pusher indexer 25, and carries it into the first cleaning machine 9. The third robot 24 picks up the cleaned semiconductor substrate W from the first cleaning machine 9, carries it into the second cleaning machine 7, and places the cleaned and dried semiconductor substrate on the substrate placing table 22. Then, the first robot 3 picks up the semiconductor substrate W, and transfers it to the dry state film thickness measuring instrument 13 in which the film thickness is measured, and the first robot 3 carrys it into the cassette 1-1 placed on the unload port of the

loading and unloading section 1.

In the above embodiment, an example in which the seed layer 107 and the plated Cu film 106 have been formed by the substrate processing apparatus having the constitution shown in FIG. 14 is shown. According to the substrate processing apparatus having the constitution shown in FIG. 14, a barrier layer 105, a seed layer 107 and a plated Cu film 106 can be formed on a semiconductor substrate W having a via hole 103 or a trench 104 of a circuit pattern formed therein, and then polished to form interconnects.

The cassette 1-1 accommodating the semiconductor substrates W before formation of the barrier layer 105 is placed on the load port of the loading and unloading section 1. The first robot 3 takes out the semiconductor substrate W from the cassette 1-1, and carries it into the seed layer forming unit 27 to form a barrier layer 105 and a seed layer 107. The barrier layer 105 and the seed layer 107 are formed by an electroless plating method. After plating, the substrate is heated to make the adhesion of the barrier layer 105 and the seed layer 107 higher. Then, a plated Cu film 106 is formed by the plated Cu film forming unit 2. At this time, the film thicknesses of the barrier layer 105 and the seed layer 107 are measured with the before-plating and after-plating film thickness measuring instrument 12. Treatment after formation of the plated Cu film 106 is the same as that described in the treatment by the substrate processing apparatus shown in FIG 14, and its explanations are omitted.

In the substrate processing apparatus shown in FIG. 15 also, interconnects are formed by forming a barrier layer 105, a seed layer 107 and a plated Cu film 106 on a semiconductor substrate

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W having a via hole 103 or a trench 104 of a circuit pattern formed therein, and polishing them.

The cassette 1-1 accommodating the semiconductor substrates W before formation of the barrier layer 105 is placed on the load port of the loading and unloading section 1. The first robot 3 takes out the semiconductor substrate W from the cassette 1-1 placed on the load port of the loading and unloading section 1, and places it on the substrate placing table 21. Then, the second robot 23 transports the semiconductor substrate W to the seed layer forming unit 27 where a barrier layer 105 and a seed layer 107 are formed. The barrier layer 105 and the seed layer 107 are formed by electroless plating. The second robot 23 brings the semiconductor substrate W having the barrier layer and the seed layer 107 formed thereon to the before-plating and after-plating film thickness measuring instrument 12 which measures the film thicknesses of the barrier layer 105 and the seed layer 107. After measurement of the film thicknesses, the semiconductor substrate W is carried into the plated Cu film forming unit 2 where a plated Cu film 106 is formed. Treatment after formation of the plated Cu film 106 is the same as that described in the treatment by the substrate processing apparatus shown in FIG 15, and its explanations are omitted.

In the above embodiment, although an example in which the plated Cu film 106 is formed to form interconnects has been shown. However, plating is not limited to Cu plating, and may be Cu alloy or other metal plating.

FIG. 16 is a view showing plan layout constitution of another embodiment of the substrate processing apparatus according to the

present invention. In the present substrate processing apparatus, there are provided a barrier layer forming unit 111, a seed layer forming unit 112, a plated film forming unit 113, an annealing unit 114, a first cleaning unit 115, a bevel and backside cleaning unit 116, a cover plating unit 117, a second cleaning unit 118, a first aligner and film thickness measuring instrument 141, a second aligner and film thickness measuring instrument 142, a first substrate reversing machine 143, a second substrate reversing machine 144, a substrate temporary placing table 145, a third film thickness measuring instrument 146, a loading and unloading section 120, a first polishing apparatus 121, a second polishing apparatus 122, a first robot 131, a second robot 132, a third robot 133, and a fourth robot 134. The film thickness measuring instruments 141, 142, and 146 are units, have the same size as the frontage dimension of other units (plating, cleaning, annealing units, and the like), and are thus interchangeable.

In this embodiment, an electroless Ru plating apparatus can be used as the barrier layer forming unit 111, an electroless Cu plating apparatus as the seed layer forming unit 112, and an electroplating apparatus as the plated film forming unit 113.

FIG. 17 is a flow chart showing the flow of the respective steps in the present substrate processing apparatus. The respective steps in the apparatus will be described according to this flow chart. First, a semiconductor substrate taken out by the first robot 131 from a cassette 120a placed on the load and unload unit 120 is placed in the first aligner and film thickness measuring unit 141, in such a state that its surface, to be plated, faces upward. In order to set a reference point for a position

at which film thickness measurement is made, notch alignment for film thickness measurement is performed, and then film thickness data on the semiconductor substrate before formation of a Cu film are obtained.

Then, the semiconductor substrate is transported to the barrier layer forming unit 111 by the first robot 131. The barrier layer forming unit 111 is such an apparatus for forming a barrier layer on the semiconductor substrate by electroless Ru plating, and the forming unit 111 forms an Ru film as a film for preventing Cu from diffusing into an interlayer insulator film (e.g. SiO_2) of a semiconductor device. The semiconductor substrate discharged after cleaning and drying steps is transported by the first robot 131 to the first aligner and film thickness measuring unit 141, where the film thickness of the semiconductor substrate, i.e., the film thickness of the barrier layer is measured.

The semiconductor substrate after film thickness measurement is carried into the seed layer forming unit 112 by the second robot 132, and a seed layer is formed on the barrier layer by electroless Cu plating. The semiconductor substrate discharged after cleaning and drying steps is transported by the second robot 132 to the second aligner and film thickness measuring instrument 142 for determination of a notch position, before the semiconductor substrate is transported to the plated film forming unit 113, which is an impregnation plating unit, and then notch alignment for Cu plating is performed by the film thickness measuring instrument 142. If necessary, the film thickness of the semiconductor substrate before formation of a Cu film may be measured again in the film thickness measuring instrument 142.

The semiconductor substrate which has completed notch alignment is transported by the third robot 133 to the plated film forming unit 113 where Cu plating is applied to the semiconductor substrate. The semiconductor substrate discharged after cleaning and drying steps is transported by the third robot 133 to the bevel and backside cleaning unit 116 where an unnecessary Cu film (seed layer) at a peripheral portion of the semiconductor substrate is removed. In the bevel and backside cleaning unit 116, the bevel is etched in a preset time, and Cu adhering to the backside of the semiconductor substrate is cleaned with a chemical liquid such as hydrofluoric acid. At this time, before transporting the semiconductor substrate to the bevel and backside cleaning unit 116, film thickness measurement of the semiconductor substrate may be made by the second aligner and film thickness measuring instrument 142 to obtain the thickness value of the Cu film formed by plating, and based on the obtained results, the bevel etching time may be changed arbitrarily to carry out etching. The region etched by bevel etching is a region which corresponds to a peripheral edge portion of the substrate and has no circuit formed therein, or a region which is not utilized finally as a chip although a circuit is formed. A bevel portion is included in this region.

The semiconductor substrate discharged after cleaning and drying steps in the bevel and backside cleaning unit 116 is transported by the third robot 133 to the substrate reversing machine 143. After the semiconductor substrate is turned over by the substrate reversing machine 143 to cause the plated surface to be directed downward, the semiconductor substrate is introduced into the annealing unit 114 by the fourth robot 134 for thereby

stabilizing a wiring portion. Before and/or after annealing treatment, the semiconductor substrate is carried into the second aligner and film thickness measuring unit 142 where the film thickness of a copper film formed on the semiconductor substrate is measured. Then, the semiconductor substrate is carried by the fourth robot 134 into the first polishing apparatus 121 in which the Cu layer and the seed layer of the semiconductor substrate are polished.

At this time, desired abrasive grains or the like are used, but fixed abrasive may be used in order to prevent dishing and enhance flatness of the face. After completion of primary polishing, the semiconductor substrate is transported by the fourth robot to the first cleaning unit 115 where it is cleaned. This cleaning is scrub-cleaning in which rolls having substantially the same length as the diameter of the semiconductor substrate are placed on the face and the backside of the semiconductor substrate, and the semiconductor substrate and the rolls are rotated, while pure water or deionized water is flowed, thereby performing cleaning of the semiconductor substrate.

After completion of the primary cleaning, the semiconductor substrate is transported by the fourth robot 134 to the second polishing apparatus 122 where the barrier layer on the semiconductor substrate is polished. At this time, desired abrasive grains or the like are used, but fixed abrasive may be used in order to prevent dishing and enhance flatness of the face. After completion of secondary polishing, the semiconductor substrate is transported by the fourth robot 134 again to the first cleaning unit 115 where scrub-cleaning is performed. After

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completion of cleaning, the semiconductor substrate is transported by the fourth robot 134 to the second substrate reversing machine 144 where the semiconductor substrate is reversed to cause the plated surface to be directed upward, and then the semiconductor substrate is placed on the substrate temporary placing table 145 by the third robot.

The semiconductor substrate is transported by the second robot 132 from the substrate temporary placing table 145 to the cover plating unit 117 where nickel-boron plating is applied onto the Cu surface with the aim of preventing oxidation of Cu due to the atmosphere. The semiconductor substrate to which cover plating has been applied is carried by the second robot 132 from the cover plating unit 117 to the third film thickness measuring instrument 146 where the thickness of the copper film is measured. Thereafter, the semiconductor substrate is carried by the first robot 131 into the second cleaning unit 118 where it is cleaned with pure water or deionized water. The semiconductor substrate after completion of cleaning is returned into the cassette 120a placed on the loading and unloading section 120.

The aligner and film thickness measuring instrument 141 and the aligner and film thickness measuring instrument 142 perform positioning of the notch portion of the substrate and measurement of the film thickness. Schematic views of the aligner and film thickness measuring instrument 142 are shown in FIGS. 18 and 19. A flow chart showing the movement of the semiconductor substrate in the aligner and film thickness measuring instrument 142 is shown in FIG. 20.

In the aligner and film thickness measuring instrument 142,

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a notch Wa is detected by a photomicrosensor 142-1, while a semiconductor substrate W is rotated, and positioning of the notch Wa is carried out at an arbitrary position. For example, the position of the notch Wa is detected to set a reference position for the film thickness measurement point, whereby the measurement points before treatment and after treatment will not be displaced from each other, and the direction of placement of the semiconductor substrate when the semiconductor substrate is introduced into the plating apparatus can be consistent.

The apparatus is configured to have a rotatable vacuum chuck 142-4, a lift 142-2, a photomicrosensor 142-1 for notch detection, an eddy current sensor 142-3 for film thickness measurement, and the like. In FIGS. 18 to 20, a semiconductor substrate W is carried in by a hand 132-1 of the second robot hand 132 (Step S1). The aligner and film thickness measuring instrument 142 raises the lift 142-2 and transfers the semiconductor substrate onto the lift 142-2 (Step S2). The hand 132-1 of the second robot 132 is retreated (Step S3), and the lift is lowered (Step S4). Thus, the semiconductor substrate W is loaded onto the vacuum chuck 142-4 (Step S5).

Then, while the vacuum chuck 142-4 is rotating, the photomicrosensor 142-1 detects the notch Wa, and the vacuum chuck 142-4 positions the notch Wa at an arbitrary position in accordance with a subsequent treatment (Step S6). If necessary, the eddy current sensor 142-3 measures the film thickness of the semiconductor substrate W at an arbitrary point (Step S7). Then, when the semiconductor substrate is introduced into the plating apparatus, the semiconductor substrate W is positioned so that the

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position of the notch Wa of the semiconductor substrate W in the plating unit 113 is fixed (Step S8). Thereafter, the vacuum chuck is brought into the OFF state (Step S9), and the lift 142-2 is raised to transfer the semiconductor substrate W (Step S10). A hand 133-1 of the third robot 133 is inserted (Step S11), and the lift 142-2 is lowered (Step S12) to transfer the semiconductor substrate W to the hand 133-1. Thus, the semiconductor substrate W is taken out (Step S13).

In FIGS. 18 and 19, the reference numeral 142-6 denotes a vacuum pump, and the vacuum pump 142-6 is connected to suction holes of the vacuum chuck 142-4 via a rotary joint 142-5. The reference numeral 142-7 denotes a motor for rotating the vacuum chuck 142-4, the reference numeral 142-9 denotes a motor for rotating an arm 142-8 having the eddy current sensor 142-3 attached thereto, and the reference numeral 142-10 denotes an actuator for moving the lifter 142-2 up and down. The reference numeral 142-11 denotes a temporary placing table for the semiconductor substrate W. The constitution and operation of the aligner and film thickness measuring instrument 141 are the same as those of the aligner and film thickness measuring instrument 142, and their explanations are omitted.

The semiconductor substrate W transferred to the barrier layer forming unit 111 which is an electroless Ru plating apparatus is first given Pd as a catalyst. Pd is applied to the semiconductor substrate W in an amount of about 30 ml, and the treatment time is about 1 minute. After the semiconductor substrate W is washed with water, the semiconductor substrate W is treated with hydrochloric acid for activation treatment. At this time,

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hydrochloric acid is applied in such a state that hydrochloric acid is a 36% solution in a concentration of about 100 ml/L and in an amount of about 30 ml, with the treatment time being about 1 minute. After the semiconductor substrate W is washed with water again, electroless Ru plating is performed. $RuCl_3 \cdot xH_2O$ is used as a ruthenium plating liquid. Treatment is performed for about 10 minutes at a substrate surface temperature of about 85℃. The film formation rate at that time is about 2 nm/min. A barrier layer is formed in this manner, and the substrate is subjected to a water washing step and a spin-drying step, thus completing treatment. According to these steps, about 20 nm of Ru is obtained on SiO_2 by electroless plating. Formation of the barrier layer 105 is not limited to electroless plating, and this barrier layer may be formed by using CVD, sputtering or electroplating. The barrier layer is not limited to Ru, and any material may be used as long as it can achieve the prevention of Cu diffusion into an interlayer insulator film such as TiN.

Electroless Cu plating, which is the seed layer forming unit 112, can employ the same apparatus as the electroless Ru plating unit. FIG. 27 is a view showing a constitution example of an electroless Cu plating unit. The structure of the electroless plating apparatus shown in FIG. 27 will be described in detail in an explanation for the second aspect of the present invention.

In the seed layer forming unit 112, a semiconductor substrate W per se is directly heated by a backside heater 315, and kept at a temperature of 70℃, for example. A plating liquid heated, for example, to 50℃ is ejected from a shower head 341, and the plating liquid is poured over substantially the entire surface of the

semiconductor substrate W. The amount of the supplied plating liquid is such that the thickness of the plating liquid on the surface of the semiconductor substrate W is about 1 mm. The semiconductor substrate W is instantaneously rotated by a motor M to perform uniform liquid wetting on the surface to be plated, and then a plated film is formed on the surface of the substrate in such a state that the semiconductor substrate W is in a stationary state.

After seed layer formation treatment is completed, the front end of a plating recovery nozzle 365 is lowered to an area near the inside of a dam member 331 located at a face peripheral edge portion of the semiconductor substrate W to suck in the plating liquid. At this time, the semiconductor substrate W is rotated, for example, at a rotational speed of 100 rpm or less, and hence the liquid remaining on the upper surface of the semiconductor substrate W can be gathered in the portion of the dam member 331 by centrifugal force. Thus, the plating liquid can be recovered with good efficiency and at a high recovery rate.

Then, holding means 311 is lowered to separate the semiconductor substrate W from the dam member 331, and the rotation of the semiconductor substrate W is started and a cleaning liquid (ultrapure water) is ejected toward the plated surface of the semiconductor substrate W from a nozzle 353 of cleaning liquid supply means 351 to cool the plated surface and perform dilution and cleaning, thereby terminating the electroless plating reaction. Next, the semiconductor substrate W is rotated at a high speed by the motor M for thereby spin-drying, and then the semiconductor substrate W is taken out from the holding means 311.

The above electroless plating liquid contains $CuSO_4 \cdot 5H_2O$, EDTA · 4Na as a complexing agent, HCHO as a reducing agent, and NaOH as an alkali for pH adjustment so that the pH becomes 12.5, and further contains α, α'-dipyridyl. The plating temperature is about 40 to 80℃. Formation of the seed layer is not limited to electroless plating, and this seed layer can be formed by using CVD, sputtering or electroplating.

The bevel and backside cleaning unit 116 can perform an edge (bevel) Cu etching and a backside cleaning at the same time, and can suppress growth of a natural oxide film of copper at the circuit formation portion on the surface of the substrate. FIG. 21 shows a schematic view of the bevel and backside cleaning unit 116. As shown in FIG. 21, the bevel and backside cleaning unit 116 has a substrate holding portion 222 positioned inside a bottomed cylindrical waterproof cover 220 and adapted to rotate a substrate W at a high speed, in such a state that the face of the substrate W faces upwardly, while holding the substrate W horizontally by spin chucks 221 at a plurality of locations along a circumferential direction of a peripheral edge portion of the substrate; a center nozzle 224 placed above a nearly central portion of the face of the substrate W held by the substrate holding portion 222; and an edge nozzle 226 placed above the peripheral edge portion of the substrate W. The center nozzle 224 and the edge nozzle 226 are directed downward. A back nozzle 228 is positioned below a nearly central portion of the backside of the substrate W, and directed upward. The edge nozzle 226 is adapted to be movable in a diametrical direction and a height direction of the substrate W.

The width of movement L of the edge nozzle 226 is set such

that the edge nozzle 226 can be arbitrarily positioned in a direction toward the center from the outer peripheral end surface of the substrate, and a set value for L is inputted according to the size, usage, or the like of the substrate W. Normally, an edge cut width C is set in the range of 2 mm to 5 mm. In the case where a rotational speed of the substrate is a certain value or higher at which the amount of liquid migration from the backside to the face is not problematic, the copper film within the edge cut width C can be removed.

Next, the method of cleaning with this cleaning apparatus will be described. First, the semiconductor substrate W is horizontally rotated integrally with the substrate holding portion 222, with the substrate being held horizontally by the spin chucks 221 of the substrate holding portion 222. In this state, an acid solution is supplied from the center nozzle 224 to the central portion of the face of the substrate W. The acid solution may be a non-oxidizing acid, and hydrofluoric acid, hydrochloric acid, sulfuric acid, citric acid, oxalic acid, or the like is used. On the other hand, an oxidizing agent solution is supplied continuously or intermittently from the edge nozzle 226 to the peripheral edge portion of the substrate W. As the oxidizing agent solution, one of an aqueous solution of ozone, an aqueous solution of hydrogen peroxide, an aqueous solution of nitric acid, and an aqueous solution of sodium hypochlorite is used, or a combination of these is used.

In this manner, the copper film, or the like formed on the upper surface and end surface in the region of the peripheral edge portion C of the semiconductor substrate W is rapidly oxidized with

the oxidizing agent solution, and is simultaneously etched with the acid solution supplied from the center nozzle 224 and spreaded on the entire face of the substrate, whereby it is dissolved and removed. By mixing the acid solution and the oxidizing agent solution at the peripheral edge portion of the substrate, a steep etching profile can be obtained, in comparison with a mixture of them which is produced in advance being supplied. At this time, the copper etching rate is determined by their concentrations. If a natural oxide film of copper is formed in the circuit-formed portion on the face of the substrate, this natural oxide is immediately removed by the acid solution spreading on the entire face of the substrate according to rotation of the substrate, and does not grow any more. After the supply of the acid solution from the center nozzle 224 is stopped, the supply of the oxidizing agent solution from the edge nozzle 226 is stopped. As a result, silicon exposed on the surface is oxidized, and deposition of copper can be suppressed.

On the other hand, an oxidizing agent solution and a silicon oxide film etching agent are supplied simultaneously or alternately from the back nozzle 228 to the central portion of the backside of the substrate. Therefore, copper or the like adhering in a metal form to the backside of the semiconductor substrate W can be oxidized with the oxidizing agent solution, together with silicon of the substrate, and can be etched and removed with the silicon oxide film etching agent. This oxidizing agent solution is preferably the same as the oxidizing agent solution supplied to the face, because the types of chemicals are decreased in number. Hydrofluoric acid can be used as the silicon oxide film etching

agent, and if hydrofluoric acid is used as the acid solution on the face of the substrate, the types of chemicals can be decreased in number. Thus, if the supply of the oxidizing agent is stopped first, a hydrophobic surface is obtained. If the etching agent solution is stopped first, a water-saturated surface (a hydrophilic surface) is obtained, and thus the backside surface can be adjusted to a condition which will satisfy the requirements of a subsequent process.

In this manner, the acid solution, i.e., etching solution is supplied to the substrate to remove metal ions remaining on the surface of the substrate W. Then, pure water is supplied to replace the etching solution with pure water and remove the etching solution, and then the substrate is dried by spin-drying. In this way, removal of the copper film in the edge cut width C at the peripheral edge portion on the face of the semiconductor substrate, and removal of copper contaminants on the backside are performed simultaneously to thus allow this treatment to be completed, for example, within 80 seconds. The etching cut width of the edge can be set arbitrarily (to 2 mm to 5 mm), but the time required for etching does not depend on the cut width.

Annealing treatment performed before the CMP process and after plating has a favorable effect on the subsequent CMP treatment and on the electrical characteristics of wiring. Observation of the surface of broad wiring (unit of several micrometers) after the CMP treatment without annealing showed many defects such as microvoids, which resulted in an increase in the electrical resistance of the entire wiring. Execution of annealing ameliorated the increase in the electrical resistance. In the

absence of annealing, thin wiring showed no voids. Thus, the degree of grain growth is presumed to be involved in these phenomena. That is, the following mechanism can be speculated: Grain growth is difficult to occur in thin wiring. In broad wiring, on the other hand, grain growth proceeds in accordance with annealing treatment. During the process of grain growth, ultrafine pores in the plated film, which are too small to be seen by the SEM (scanning electron microscope), gather and move upward, thus forming microvoid-like depressions in the upper part of the wiring. The annealing conditions in the annealing unit 114 are such that hydrogen (2% or less) is added in a gas atmosphere, the temperature is in the range of 300℃ to 400℃, and the time is in the range of 1 to 5 minutes. Under these conditions, the above effects were obtained.

The features of the substrate processing apparatus having the above-described constitution are enumerated as follows:

Pretreatment, cleaning and drying can be performed in each film forming unit, and no contaminants are brought into a next step.

In each unit incorporated in the present apparatus, various chemical liquids are used. Even in the same unit, different chemical liquids may be selected depending on differences in the process. If different chemical liquids are mixed, the treating effects of the chemical liquids may change, or crystals of compounds may be deposited, thus not only affecting the substrate being treated, but also affecting the process treatment of a next semiconductor substrate which will be introduced subsequently. If the transport means is a robot hand, the hand is contaminated. Thus, each time the substrate is transported, various chemical liquids adhere thereto.

Therefore, the present apparatus is characterized in that before transfer to the next unit, i.e., the next step in the semiconductor manufacturing apparatus, the semiconductor substrate is subjected in the unit to treatment which allows no chemical liquid for treatment to remain, and then the treated semiconductor substrate is taken out therefrom. Thus, the chemical liquid is not brought into a separate unit. For example, when the substrate is to be transferred from the electroless plating unit for a barrier layer formation step to the electroplating unit for a plating step for formation of buried wiring, the substrate is subjected to cleaning treatment and drying treatment in the electroless plating unit. Thus, an alkaline electroless plating liquid is prevented from being brought into the electroplating unit in which an acidic plating liquid is used.

At the time of transfer of the substrate from the plating step to the CMP step, cleaning treatment and drying treatment, as well as plating treatment, are carried out in the electroplating unit so that the acidic plating liquid is not brought into the CMP step.

The plated film forming unit 113 for performing a plating step for buried wiring is characterized in that treatment with a surface active agent, precoating treatment, and the like are possible. Because of this characteristic, pretreatment can be performed in the plated film forming unit 113 (in the single unit) immediately before electroplating, and hence filling of liquid into fine pores is improved. Moreover, a cleaning mechanism and a spin-drying mechanism are present in the plated film forming unit 113 (in the single unit), and hence the semiconductor substrate

W for intercellular movement can be put into a desired wet state such as liquid removal or drying. The cleaning mechanism and the spin-drying mechanism, in particular, can clean and dry not only the semiconductor substrate, but also the seal material and the cathode contact, and thus have the effects of remarkably decreasing the replacement frequency of these expendable members and increasing the continuous operating time of the entire apparatus.

Flexible incorporation of the units and flexible construction of the process can be performed in a short period of time. FIGS. 22A to 22D, 23A and 23B, and 24A and 24B are views showing constitution examples in which the respective units in the substrate processing apparatus are interchangeable. FIGS. 22A and 22B are plan views of bed plates for supporting respective units constituting the present substrate processing apparatus, FIG. 22C is a front view of the base plate, and FIG. 22D is a sectional view taken along line A-A of FIG. 22B. FIG. 23A is a front view of each unit of the present substrate processing apparatus, and FIG. 23B is a sectional view taken along line B-B of FIG. 23A. FIG. 24A is a front view showing a state in which each unit of the present substrate processing apparatus is placed on the base plate, and FIG. 24B is a sectional view taken along line C-C of FIG. 24A.

As shown in the drawings, two rails (comprising, for example, SUS material) 302, 302 are placed on an upper surface of a bed plate 300 for placing thereon each unit 301 of the present substrate processing apparatus, in parallel and with narrower spacing than the frontage dimension D of each unit 301 so as to be placed in the bed plate 300 (the upper surface of the bed plate 300 is substantially flush with the upper surfaces of the rails 302, 302).

At an intermediate position between the rails, one guide bar (comprising, for example, nylon resin material) 303 is placed so as to protrude from the upper surface of the bed plate 300. The bottom of each unit 301 is double-bottomed, and four rollers 304 are attached to an upper bottom portion 305 by screws 308, while a groove 307 to be engaged with the guide bar 303 is provided in a lower bottom portion 306. The height of each roller 304 can be adjusted by the screw 308.

The screw 308 is adjusted to adjust a bottom portion of each roller 304 so as to protrude slightly (e.g. by about 1 mm) from the lower bottom portion 306. In this state, when the unit 301 is inserted such that the guide bar 303 is engaged with the groove 307 of the lower bottom portion 306 of the unit 301, the unit 301 is guided by the guide bar and settles at a predetermined position. In this state, a gap d corresponding to a protrusion of the roller 304 exists between the lower bottom portion 306 and the upper surface of the bed plate 300, as shown in FIG. 24A. Each screw 308 is loosened in such a state that each unit 301 is settled at the predetermined position for thereby retracting each roller 304, and thus the lower bottom portion 306 of the unit 301 contacts the upper surface of the bed plate 300 (not shown). In this state, each unit 301 is fixed to the bed plate 300 by fixing screws (not shown).

Each unit is loaded such that its carry-in and carry-out opening is directed in the direction of the transport robots 131 to 134 (see FIG. 16). The width of each unit 300 facing the robot, i.e., the frontage dimension D, is of the same size. During loading, the unit is inserted along the rails 302, 302 onto the unit loading

surface of the bed plate 300 of the present apparatus as described above, and thus the unit can be easily loaded. The loaded unit 301 may be pulled in the reverse direction when it is removed from the body of the apparatus.

In the field of semiconductor manufacturing, innovations in techniques are making rapid progress. By imparting an easily replaceable structure to each unit 301 constituting the apparatus as described above, some of the units 301 can be easily replaced with new units, without the need to replace the entire apparatus. Thus, renewal of the functions of the entire apparatus can be achieved at a low cost in a short period of time. Also, on the precondition that the unit 301 will be replaced in the above manner, the apparatus is designed such that the control system can easily cope with the replacement. The present apparatus can freely set whether a process treatment is performed or not in the loaded unit 301 (skip function for the unit), and can freely set a treatment route of the semiconductor substrate W (sequence of use of the units). Thus, not only in case the unit has been replaced, but also in case treatment should be performed by a different process, the functions of the apparatus can be flexibly modified. Particularly, in order to meet demands for manufacturing of a wide variety of products, and low volume production in recent years, it has become important to possess many kinds of small scale lines. Thus, the above structure which enables necessary units to be easily and freely combined is particularly useful.

FIG. 25 is a view showing plan layout constitution of another embodiment of the substrate processing apparatus according to the present invention. The present substrate processing apparatus is

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such a substrate processing apparatus applicable to small-scale, low volume production of a wide variety of products, like manufacturing of system LSIs required for digital information household electrical appliances. In the substrate processing apparatus, there are provided a first plated film forming unit 401, a second plated film forming unit 402, a bevel and backside cleaning unit 403, an annealing unit 404, an aligner and film thickness measuring unit 405, and a loading and unloading section 408 such that they surround a first robot 406 and a second robot 407. Two indexers 409, 409 are placed on the loading and unloading section 408, and a cassette 410 can be placed on each of the indexers. In FIG. 25, the reference numeral 411 denotes a chemical liquid supply unit, the reference numeral 412 an electrical component unit, the reference numeral 413 a touch panel, and the reference numeral 414 a duct for air intake or exhaust.

The indexer 409 is such a mechanism which can raise and lower a cassette placed thereon to position the cassette in a height direction in alignment with a substrate taken out by the first robot 406. The first robot 406 accesses the same height position. In the present substrate processing apparatus, the first robot 406 takes out the substrate, which has a barrier layer and a seed layer formed by another apparatus, from the cassette 410 on the indexer 409, and transports it to the aligner and film thickness measuring unit 405. After alignment of the notch and film thickness measurement before film formation are performed by the aligner and film thickness measuring unit 405, the second robot 407 takes out the substrate from the aligner and film thickness measuring unit 405, and transports it to the first plated film forming unit 401

or the second plated film forming unit 402 where copper plating is applied.

The substrate to which copper plating has been applied, is transported by the second robot 407 to the aligner and film thickness measuring unit 405, and the film thickness of the substrate after plating is measured with the aligner and film thickness measuring unit 405. The first robot 406 takes out the substrate from the aligner and film thickness measuring unit 405, and transports it to the bevel and backside cleaning unit 403. After the substrate is cleaned in the bevel and backside cleaning unit 403, it is transported to the annealing unit 404. After the substrate is annealed in the annealing unit 404, the first robot 406 returns the substrate which has been cleaning to the cassette 410 on the indexer 409.

The first plated film forming unit 401 and the second plated film forming unit 402 may be set for the same process, and plating treatment of a plurality of substrates may be performed in parallel. Alternatively, different processes may be used in the first plated film forming unit 401 and the second plated film forming unit 402, and during one of the processes, one of the units may be kept at rest, while only the other unit may be used. Also, the annealing unit 404 and the bevel and backside cleaning unit 403 can be replaced with plated film forming units for performing different processes.

In the present substrate processing apparatus, the width of sides 401a, 402a of the first plated film forming unit 401 and the second plated film forming unit 402 facing the second robot 407, namely the frontage dimension D is of the same size as the frontage dimension of the annealing unit 404, the bevel and backside cleaning

unit 403, the aligner and film thickness measuring unit 405, the cleaning units 115, 118, the seed layer forming unit 112, the barrier layer forming unit 111, the cover plating unit 117, the aligner and film thickness measuring units 141, 142, the film thickness measuring unit 146, the substrate reversing machines 143, 144, and the temporary placing table 145 of FIG. 16 (although the frontage dimension in some parts is not shown to be of the same size in the drawing). Thus, when a new process is to be introduced, these units can be easily replaced by other units, and hence renewal of the apparatus can be performed at a low cost in a short time. The aligner and film thickness measuring unit 405 is also of the same size as the frontage dimension of other units, and they are interchangeable.

With the above-described layout of the substrate processing apparatus which is mainly adopted, a plurality of the substrate processing apparatuses are installed in the plant, and the constitutions of the units to be loaded thereon are changed, whereby the apparatuses can be used in different wiring processes. In case that high volume production is required temporarily, the apparatuses can be rapidly modified into substrate processing apparatuses composed of the same units to meet the requirement.

In the foregoing explanations of the embodiments, an example for forming the plated Cu film 106 by electroplating has been described, but the plated Cu film 106 can be formed by electroless plating.

According to the first aspect of the present invention as described above, the following excellent effects can be obtained.

(1) Processing in which metal plating is applied onto a

semiconductor substrate having a groove and/or a hole for a wiring pattern formed on a surface thereof, and having a barrier layer and a power supply seed layer formed thereon, the barrier layer, the power supply seed layer and a plated metal film are polished and removed, and the substrate is cleaned and dried to form interconnects, can be performed continuously by one apparatus. Thus, compared with a case in which respective processing steps are performed by separate apparatuses, the entire apparatus can be compact, a wide installation space is not needed, the initial cost and running cost for the apparatus can be decreased, and interconnects can be formed in a short processing time.

(2) Processing in which a power supply seed layer and a plated metal film are applied onto a semiconductor substrate having a groove and/or a hole for a wiring pattern formed on a surface thereof, and having a barrier layer formed thereon, the power supply seed layer and the plated metal film are polished and removed, and the substrate is cleaned and dried to form interconnects, can be performed continuously by one apparatus. Thus, compared with a case in which respective processing steps are performed by separate apparatuses, the entire apparatus can be compact, a wide installation space is not needed, the initial cost and running cost for the apparatus can be decreased, and interconnects can be formed in a short processing time.

(3) Processing in which a barrier layer, a power supply seed layer and a plated metal film are applied onto a semiconductor substrate having a groove and/or a hole for a wiring pattern formed on a surface thereof, the barrier layer, the power supply seed layer and the plated metal film are polished and removed, and the

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substrate is cleaned and dried to form interconnects, can be performed continuously by one apparatus. Thus, compared with a case in which respective processing steps are performed by separate apparatuses, the entire apparatus can be compact, a wide installation space is not needed, the initial cost and running cost for the apparatus can be decreased, and interconnects can be formed in a short processing time.

(4) By recording the results of measurement of the film thicknesses, the remaining film, and the initial film thicknesses of the respective layers measured with the film thickness measuring section and the remaining film measuring section, it is possible to utilize the records as data for controlling the treatment time of a subsequent step, and as data for judging the good or poor state of each treatment step, or judging whether the semiconductor substrate after completion of the interconnect formation treatment is good or poor.

(5) It is possible to provide a substrate processing apparatus which can easily cope with a change in the substrate treatment process, and can achieve renewal of the function of the entire substrate processing apparatus at a low cost in a short time.

(6) While a substrate holding portion is holding a semiconductor substrate faceup, a plating liquid is filled between a surface to be plated and an anode of an electrode arm portion to perform plating treatment. After plating treatment, the plating liquid between the surface to be plated and the anode of the electrode arm portion is discharged, and the electrode arm portion is raised to release the plated surface. Thus, other treatments associated with plating treatment, such as pretreatment and cleaning and drying

treatment, can be performed before and after plating treatment, while the semiconductor substrate is being held by the substrate holding portion.

(7) The precoating treatment, plating treatment and water washing treatment can be performed by a plating unit, thus improving time efficiency.

(8) Since the respective units are adapted to be interchangeable, the apparatus can freely and easily deal with changes in the substrate treatment process, and renewal of the functions of the entire substrate processing apparatus can be achieved at a low cost in a short time.

(9) Processing in which metal plating is applied onto a semiconductor substrate having a groove and/or a hole for a wiring pattern formed on a surface thereof, and having a barrier layer and a power supply seed layer formed thereon, the barrier layer, the power supply seed layer, and a plated metal film are polished and removed, and the substrate is cleaned and dried to form interconnects, can be performed continuously by one apparatus. Thus, compared with a case in which respective treatment steps are performed by separate apparatuses, the entire apparatus can be compact, a wide installation space is not needed, the initial cost and running cost for the apparatus can be decreased, and interconnects can be formed in a short processing time.

(10) Processing in which a power supply seed layer and a plated metal film are applied onto a semiconductor substrate having a groove and/or a hole for a wiring pattern formed on a surface thereof, and having a barrier layer formed thereon, the power supply seed layer and the plated metal film are polished and removed, and the

substrate is cleaned and dried to form interconnects, can be performed continuously. Thus, interconnects can be formed in a short processing time.

(11) Processing in which a barrier layer, a power supply seed layer and a plated metal film are applied onto a semiconductor substrate having a groove and/or a hole for a wiring pattern formed on a surface thereof, the power supply seed layer and the plated metal film are polished and removed, and the substrate is cleaned and dried to form interconnects, can be performed continuously. Thus, interconnects can be formed in a short procesing time.

Next, a second aspect of the present invention will be described in detail with reference to FIGS. 26A, 26B, 26C to 29. An electroless plating apparatus according to this embodiment is used, for example, to form a seed layer or wiring comprising a copper layer by applying electroless copper plating onto the surface of a semiconductor substrate W. An example of this plating process will be described with reference to FIGS. 26A to 26C.

In the semiconductor substrate W, as shown in FIG. 26A, an insulating film 2 comprising SiO_2 is deposited on a conductive layer 1a of a substrate 1 on which semiconductor devices are formed, a via hole 3 and a trench 4 for an interconnect are formed by lithography and etching technology, a barrier layer 5 comprising TiN or the like is formed thereon, and a seed layer 7 is further formed thereon by electroless copper plating. The seed layer 7 may be formed beforehand by sputtering, and a reinforcing seed layer for reinforcing the seed layer 7 may be formed thereon by electroless copper plating. As shown in FIG. 26B, copper plating is applied onto the surface of the semiconductor substrate W to

fill copper into the via hole 3 and the trench 4 of the semiconductor substrate W and deposit a copper layer 6 on the insulating film 2. Thereafter, the copper layer 6 on the insulating film 2 is removed by chemical and mechanical polishing (CMP) to make the surface of the copper layer 6, filled into the via hole 3 and the trench 4 for an interconnect, flush with the surface of the insulating film 2, as shown in FIG. 26C. An interconnect protective film 8 is formed on the exposed metal surface. The reinforcing seed layer can be formed by electroless plating as stated above, but can also be formed by electroplating. When the reinforcing seed layer is to be formed by electroplating, it can be formed by the plated metal film forming unit of the present invention, but can also be formed by a so-called cup-type electroplating unit which performs electroplating while holding a surface, to be plated, of the substrate so as to face downward.

FIG. 27 is a schematic constitution drawing of the electroless plating apparatus of the present invention. As shown in FIG. 27, this electroless plating apparatus comprises holding means 311 for holding a semiconductor substrate W to be plated on its upper surface, a dam member (plating liquid holding mechanism) 331 for contacting a peripheral edge portion of a surface to be plated (upper surface) of the semiconductor substrate W held by the holding means 311 to seal the peripheral edge portion, and a shower head (an electroless plating treatment liquid (scattering) supply means) 341 for supplying a plating liquid (an electroless plating treatment liquid) to the surface, to be plated, of the semiconductor substrate W having the peripheral edge portion sealed with the dam member 331. The electroless plating apparatus

further comprises cleaning liquid supply means 351 disposed near an upper outer periphery of the holding means 311 for supplying a cleaning liquid to the surface, to be plated, of the semiconductor substrate W, a recovery vessel 361 for recovering a cleaning liquid or the like (plating waste liquid) discharged, a plating liquid recovery nozzle 365 for sucking in and recovering the plating liquid held on the semiconductor substrate W, and a motor (rotational drive means) M for rotationally driving the holding means 311. The respective members will be described below.

The holding means 311 has a substrate placing portion 313 on its upper surface for placing and holding the semiconductor substrate W. The substrate placing portion 313 is adapted to place and fix the semiconductor substrate W. Specifically, the substrate placing portion 313 has a vacuum attracting mechanism (not shown) for attracting the semiconductor substrate W to a backside thereof by vacuum suction. A backside heater (heating means) 315, which is planar and heats the surface, to be plated, of the semiconductor substrate W from underside to keep it warm, is installed on the backside of the substrate placing portion 313. The backside heater 315 is composed of, for example, a rubber heater. This holding means 311 is adapted to be rotated by the motor M and is movable vertically by raising and lowering means (not shown).

The dam member 331 is tubular, has a seal portion 333 provided in a lower portion thereof for sealing the outer peripheral edge of the semiconductor substrate W, and is installed so as not to move vertically from the illustrated position.

The shower head 341 is of a structure having many nozzles provided at the front end for scattering the supplied plating liquid

in a shower form and supplying it substantially uniformly to the surface, to be plated, of the semiconductor substrate W. The cleaning liquid supply means 351 has a structure for ejecting a cleaning liquid from a nozzle 353.

The plating liquid recovery nozzle 365 is adapted to be movable upward and downward and swingable, and the front end of the plating liquid recovery nozzle 365 is adapted to be lowered inwardly of the dam member 331 located on the upper surface peripheral edge portion of the semiconductor substrate W and to suck in the plating liquid on the semiconductor substrate W.

Next, the operation of the electroless plating apparatus will be described. First, the holding means 311 is lowered from the illustrated state to provide a gap of a predetermined dimension between the holding means 311 and the dam member 331, and the semiconductor substrate W is placed on and fixed to the substrate placing portion 313. An 8 inch wafer, for example, is used as the semiconductor substrate W.

Then, the holding means 311 is raised to bring its upper surface into contact with the lower surface of the dam member 331 as illustrated, and the outer periphery of the semiconductor substrate W is sealed with the seal portion 333 of the dam member 331. At this time, the surface of the semiconductor substrate W is in an open state.

Then, the semiconductor substrate W itself is directly heated by the backside heater 315 to render the temperature of the semiconductor substrate W, for example, 70℃ (maintained until termination of plating). Then, the plating liquid heated, for example, to 50℃ is ejected from the shower head 341 to pour the

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plating liquid over substantially the entire surface of the semiconductor substrate W. Since the surface of the semiconductor substrate W is surrounded by the dame member 331, the poured plating liquid is all held on the surface of the semiconductor substrate W. The amount of the supplied plating liquid may be a small amount which will become a 1 mm thickness (about 30 ml) on the surface of the semiconductor substrate W. The depth of the plating liquid held on the surface to be plated may be 10 mm or less, and may be even 1 mm as in this embodiment. If a small amount of the supplied plating liquid is sufficient as in the present embodiment, the heating apparatus for heating the plating liquid may be of a small size. In this embodiment, the temperature of the semiconductor substrate W is raised to 70℃, and the temperature of the plating liquid is raised to 50℃ by heating. Thus, the surface, to be plated, of the semiconductor substrate W becomes, for example, 60℃, and hence a temperature optimal for a plating reaction in this embodiment can be achieved. If the semiconductor substrate W itself is adapted to be heated as described above, the temperature of the plating liquid requiring a great electric power consumption for heating need not be raised so high. This is preferred, because the electric power consumption can be decreased, and a change in the property of the plating liquid can be prevented. The electric power consumption for heating of the semiconductor substrate W itself may be small, and the amount of the plating liquid stored on the semiconductor substrate W is also small. Thus, heat retention of the semiconductor substrate W by the backside heater 315 can be performed easily, and the capacity of the backside heater 315 may be small, and the apparatus can be made compact. If means

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for directly cooling the semiconductor substrate W itself is used, switching between heating and cooling may be performed during plating to change the plating conditions. Since the plating liquid held on the semiconductor substrate is in a small amount, temperature control can be performed with good sensitivity.

The semiconductor substrate W is instantaneously rotated by the motor M to perform uniform liquid wetting of the surface to be plated, and then plating of the surface to be plated is performed in such a state that the semiconductor substrate W is in a stationary state. Specifically, the semiconductor substrate W is rotated at 100 rpm or less for only 1 second to uniformly wet the surface, to be plated, of the semiconductor substrate W with the plating liquid. Then, the semiconductor substrate W is kept stationary, and electroless plating is performed for 1 minute. The instantaneous rotating time is 10 seconds or less at the longest.

After completion of the plating treatment, the front end of the plating liquid recovery nozzle 365 is lowered to an area near the inside of the dam member 331 on the peripheral edge portion of the semiconductor substrate W to suck in the plating liquid. At this time, if the semiconductor substrate W is rotated at a rotational speed of, for example, 100 rpm or less, the plating liquid remaining on the semiconductor substrate W can be gathered in the portion of the dam member 331 on the peripheral edge portion of the semiconductor substrate W under centrifugal force, so that recovery of the plating liquid can be performed with a good efficiency and a high recovery rate. The holding means 311 is lowered to separate the semiconductor substrate W from the dam member 331. The semiconductor substrate W is started to be rotated,

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and the cleaning liquid (ultrapure water) is jetted at the plated surface of the semiconductor substrate W from the nozzle 353 of the cleaning liquid supply means 351 to cool the plated surface, and simultaneously perform dilution and cleaning, thereby stopping the electroless plating reaction. At this time, the cleaning liquid jetted from the nozzle 353 may be supplied to the dam member 331 to perform cleaning of the dam member 331 at the same time. The plating waste liquid at this time is recovered into the recovery vessel 361 and discarded.

The plating liquid once used is not reused, but thrown away. As stated above, the amount of the plating liquid used in this apparatus can be made very small, compared with that in the prior art. Thus, the amount of the plating liquid which is discarded is small, even without reuse. In some cases, the plating liquid recovery nozzle 365 may not be installed, and the plating liquid which has been used may be recovered as a plating waste liquid into the recovery vessel 361, together with the cleaning liquid.

Then, the semiconductor substrate W is rotated at a high speed by the motor M for spin-drying, and then the semiconductor substrate W is removed from the holding means 311.

FIG. 28 is a schematic constitution drawing of an electroless plating apparatus constituted using another embodiment of the present invention. The embodiment of FIG. 28 is different from the aforementioned embodiment in that instead of providing the backside heater 315 in the holding means 311, lamp heaters (heating means) 317 are disposed above the holding means 311, and the lamp heaters 317 and a shower head 341-2 are integrated. For example, a plurality of ring-shaped lamp heaters 317 having different radii

are provided concentrically, and many nozzles 343-2 of the shower head 341-2 are open in a ring form from the gaps between the lamp heaters 317. The lamp heaters 317 may be composed of a single spiral lamp heater, or may be composed of other lamp heaters of various structures and arrangements.

Even with this constitution, the plating liquid can be supplied from each nozzle 343-2 to the surface, to be plated, of the semiconductor substrate W substantially uniformly in a shower form. Further, heating and heat retention of the semiconductor substrate W can be performed by the lamp heaters 317 directly uniformly. The lamp heaters 317 heat not only the semiconductor substrate W and the plating liquid, but also ambient air, thus exhibiting a heat retention effect on the semiconductor substrate W.

Direct heating of the semiconductor substrate W by the lamp heaters 317 requires the lamp heaters 317 with a relatively large electric power consumption. In place of such lamp heaters 317, lamp heaters 317 with a relatively small electric power consumption and the backside heater 315 shown in FIG. 27 may be used in combination to heat the semiconductor substrate W mainly with the backside heater 315 and to perform heat retention of the plating liquid and ambient air mainly by the lamp heaters 317. In the same manner as in the aforementioned embodiment, means for directly or indirectly cooling the semiconductor substrate W may be provided to perform temperature control.

Plating was actually performed using the electroless plating apparatus shown in FIG. 27 and the conventional electroless plating apparatus shown in FIG. 41, and the results were compared. The

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conditions for and the results of the experiments are shown below.

[Electroless Cu plating sample]

An 8 inch semiconductor substrate has a barrier layer of TaN (30 nm) and a seed layer (film applied all over) of Cu (50 nm) formed on silicon.

[Plating specifications]

(1) Plating method according to the present invention

Process: A semiconductor substrate W is set on the holding means 311 heated by the backside heater 315 (70℃), and the dam member 331 is set on the semiconductor substrate W. Then, the plating liquid (50℃) is supplied for 5 seconds in an amount of only 30 ml from the shower head 341 in such a state that the semiconductor substrate W is in a stationary state. Thereafter, the semiconductor substrate W is rotated at 100 rpm for only 1 second to wet the surface of the semiconductor substrate W uniformly with the plating liquid, and the semiconductor substrate W is held in a stationary state for 1 minute. Then, the plating liquid is recovered by the plating liquid recovery nozzle 365, and then the dam member 331 is separated from the surface of the semiconductor substrate W. While the semiconductor substrate W is being rotated (800 rpm), the cleaning liquid (ultrapure water) is supplied onto the surface of the semiconductor substrate W for 30 seconds for water washing, thereby stopping a plating reaction. Supply of the cleaning liquid is stopped, and the semiconductor substrate W is spin-dried (1000 rpm, 30 sec) and then taken out.

(2) Plating method according to a conventional example

Process: A semiconductor substrate W is set on the holding means 81, and a plating liquid of 70℃ is dripped onto the center of the

semiconductor substrate W for 1 minute (600 ml/min) in such a state that the semiconductor substrate W is rotated at 40 rpm. After dripping of the plating liquid is finished, a cleaning liquid (ultrapure water) is supplied onto the surface of the semiconductor substrate W for 30 seconds, while the semiconductor substrate W is continued to be rotated, thus performing water washing and stopping the plating reaction. Then, the semiconductor substrate W is withdrawn from the holding means 81, and dried separately with a dryer.

FIGS. 29A and 29B are views showing the results of measurement of the film thicknesses, on the X axis, of semiconductor substrates W subjected to the electroless plating according to the above respective methods. FIG. 29A is a view showing electroless Cu film thickness inplane distribution according to the present plating method, and FIG. 29B is a view showing electroless Cu film thickness inplane distribution according to the conventional plating method. In FIGS. 29A and 29B, the horizontal axis represents locations of the wafer (substrate), while the vertical axis represents the thickness of the plated film. As shown in FIGS. 29A and 29B, in the plating method according to the present invention, the film thickness is uniform throughout the semiconductor substrate W. Whereas in the plating method according to the conventional example, the film thickness is extremely smaller at the center of the semiconductor substrate W. The plating method according to the present invention was verified to improve the inplane uniformity of the plated film thickness remarkably.

The embodiment of the present invention has been described

above, but the present invention is not limited to the above embodiment, and various modifications are possible within the scope of the claims and the scope of the technical ideas described in the specification and drawings. For example, the electroless plating apparatus according to the present invention is not limited to the formation of a seed layer and a copper layer for interconnects, but can be used in the formation of a wiring protective film.

Further, the electroless plating apparatus according to the present invention can also be used in the pretreatment step and the catalyst treatment step for electroless plating. That is, in the above embodiment, for example, electroless plating was performed by supplying an electroless plating liquid from the shower head 341 to the surface, to be plated, of the semiconductor substrate W. However, other electroless plating treatment liquid for use in the pretreatment step or the catalyst treatment step for electroless plating may be supplied from the shower head 341 before the electroless plating liquid supply step. Thus, these treatment steps can also be performed by this electroless plating apparatus, together with the electroless plating step.

In the above embodiment, plating was carried out in such a state that the plating liquid is held on the surface to be plated, and the substrate is kept stationary. However, the substrate may be rotated slowly to such a degree that uneven plating does not occur.

Furthermore, the shower head is not restrictive, if the plating liquid can be supplied in a scattered manner to the surface to be plated. For example, there may be provided a nozzle which supplies the plating liquid while performing a swinging motion or

a translational motion.

In the above embodiment, cleaning was performed in the cleaning step after plating by supplying the cleaning liquid while the holding means 311 is kept to be separated from the dam member 331. However, the cleaning may be performed by supplying the cleaning liquid while the holding means 311 is not separated from the dam member 331, and by causing the cleaning liquid to overflow from the upper edge of the dam member 331. When the plating liquid remaining inside is diluted by supplying the cleaning liquid, the liquid temperature is simultaneously lowered, whereupon the electroless plating reaction comes to an end. Incidentally, the holding means 311 and the dam member 331 may be separated by raising the dam member 331, instead of lowering the holding means 311.

During heating of the semiconductor substrate W by the backside heater 315 (especially during the period from start of heating to contact of the plating liquid with the surface), it is desirable to blow an inert gas such as an argon (Ar) gas onto the surface, to be plated, of the semiconductor substrate W in order to prevent oxidation. If a seed layer formed by sputtering or the like is exposed at the surface of the semiconductor substrate W, heating of the seed layer may result in the oxidation of the surface of the seed layer. Thus, the use of such a gas is particularly effective when it is attempted to prevent the oxidation and form a plated layer of more uniform film thickness on the seed layer.

In the above embodiment, the backside heater 315 or the lamp heater 317 was used as the heating means for the semiconductor substrate W, but a heater may be further provided at other position close to the substrate. Moreover, instead of using the heater,

or in addition to the use of the heater, the temperature of surroundings for performing electroless plating may be made substantially equal to the electroless plating treatment temperature (the temperature preferred for plating of the surface, to be plated which is the reaction surface), whereby heat dissipation can be prevented to keep the treatment temperature constant. In this case, a heated gas may be supplied in the surroundings of the substrate, for example.

In the above embodiment, the step of instantaneously rotating the substrate was used as the step of bringing the electroless plating treatment liquid supplied onto the surface, to be plated, of the substrate in contact with the surface to be plated. Other steps may be the step of spreading the electroless plating treatment liquid all over the surface to be plated, by moving the substrate, or moving the supplied electroless plating treatment liquid. That is, the step of moving the substrate is, for example, to vibrate or swing (shakingly move) the substrate to which the electroless plating treatment liquid is supplied. The step of moving the supplied electroless plating treatment liquid is, for example, to rake the supplied electroless plating treatment liquid by using a raking member, or to blow air onto the liquid surface.

As described in detail above, the second aspect of the present invention offers the following excellent effects:

(1) The electroless plating treatment liquid is stored and held on the surface to be plated for a predetermined time to treat the surface to be plated. Thus, treatment of the surface can be performed using a small amount of the electroless plating treatment

liquid, so that a cost reduction can be achieved. Further, a pump of a small size can be used as a pump for supplying the electroless plating treatment liquid, the electroless plating apparatus can be made compact, and the cost for a clean room housing the apparatus can be reduced. Since a small amount of the electroless plating treatment liquid is used, heating and warmth retention of the electroless plating treatment liquid can be easily and promptly performed. Furthermore, there is no need to constantly heat a large amount of the electroless plating treatment liquid, and hence deterioration of the electroless plating treatment liquid is not promoted.

(2) Since the amount of the electroless plating treatment liquid used may be small, discarding this liquid as it is does not lead to a cost increase. A fresh electroless plating treatment liquid can be always used, and the composition of the treatment liquid can be made constant. By-products generated when the liquid is used in a circulated manner are not deposited in the system, and stable treatment such as plating can be carried out easily. A liquid analyzer or a liquid adjustor for the plating liquid becomes unnecessary, and a decrease in the equipment cost and a decrease in the clean room cost can be achieved. Since a large amount of the electroless plating treatment liquid is not used in a circulated manner, particles are difficult to be generated from the constituent members of the apparatus, thus obviating the need for a filter.

(3) Because treatment is performed in such a state that the electroless plating treatment liquid is held on the surface to be plated, the treatment conditions for the respective parts of the

surface to be plated can be equalized, in comparison with a case in which treatment is performed in such a state that the electroless plating treatment liquid is dripped onto the surface to be plated. Consequently, the inplane uniformity of the thickness of the resulting plated film can be achieved. Particularly, when treatment is performed in such a state that the substrate is in a stationary state, heat dissipation due to the peripheral speed of the substrate does not take place, the reaction temperature can be uniformized without a fall in the temperature, and a stable process can be obtained, in comparison with a case in which the treatment is performed in such a state that the substrate is rotated.

(4) The electroless plating treatment liquid is brought into contact with the surface, to be plated, of the substrate in such a state that the substrate is heated to a temperature higher than the temperature of the electroless plating treatment liquid. Thus, the temperature of the plating liquid requiring a great electric power consumption for heating need not be raised so much, and the electric power consumption can be decreased, and change of the composition of the plating liquid can be prevented.

(5) In the case where electroless plating treatment liquid supply means is provided above the surface to be plated, and adapted to supply the electroless plating treatment liquid in a scattered state, the electroless plating treatment liquid can be simultaneously supplied to the entire surface, to be plated, of the substrate substantially uniformly, and temperature control of the electroless plating treatment liquid can be performed stably.

(6) The electroless plating apparatus comprises holding means

for holding a substrate; a plating liquid holding mechanism for sealing the periphery of the surface to be plated; and electroless plating treatment liquid supply means for supplying an electroless plating treatment liquid to, and storing the electroless plating treatment liquid on, the surface, to be plated, of the substrate sealed with the plating liquid holding mechanism. Thus, a pretreatment liquid, a catalytic treatment liquid, an electroless plating liquid or the like can be used as the electroless plating treatment liquid while switching any of these liquids, and hence a series of electroless plating steps can be carried out in a single cell, and the apparatus can be made compact.

Next, a third aspect of the present invention will be described with reference to FIGS. 30 to 39. The third aspect of the present invention relates to various substrate processing apparatuses such as a substrate plating apparatus and a substrate polishing apparatus, and more particularly to a substrate processing apparatus preferred for detecting a substrate surface state of a substrate to be treated, such as film thickness. The present invention is applicable to all substrate processing apparatuses that perform transportation and treatment of the substrate. Here, an explanation will be made, particularly, for cases in which the substrate processing apparatus is applied for measurement of film thickness in a copper plating apparatus and a CMP apparatus for use in the formation of wiring of a semiconductor substrate.

FIG. 30 is a plan view showing an example of a plating apparatus to which the present invention is applied. This plating apparatus comprises two wafer cassettes 510, 510 for accommodating

a plurality of substrates therein, a transport robot 514 for withdrawing the substrate from the wafer cassettes 510, 510 and transporting the substrate, and two plating modules (substrate processing modules) 512, 512, each of which performs a series of plating treatment steps consisting of plating, cleaning and drying of the substrate. The reference numeral 518 denotes liquid supply equipment with a plating liquid tank 516.

The constitution of the plating module 512 is the same as the constitution shown in FIG. 9, and hence the module 512 will be described with reference to FIG. 9. This plating module 512 can perform a series of treatments consisting of plating, cleaning and drying. That is, a substrate W is held with a surface thereof to be treated facing upward at three positions A, B and C by a substrate holding portion 2-9. After the substrate W is carried in and placed at the position A, a plating liquid is supplied at the position B onto the surface to be treated in such a state that a cathode electrode 2-17 is connected to an area close to the outer periphery of the substrate W. An anode electrode (not shown) is brought into contact with the plating liquid from above, and a voltage is applied to perform electroplating. After completion of plating, the plating liquid on the substrate W is sucked in by a nozzle (not shown). Instead, cleaning water is supplied at the position C, and the substrate holding portion 2-9 is rotated to spread cleaning water on the entire surface of the substrate W, thereby performing cleaning. After cleaning, supply of the cleaning water is stopped, and the rotational speed of the substrate W is increased to remove the cleaning water and perform spin-drying. If necessary, a precoating treatment for applying, for example,

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a surface active agent may be performed before plating, or cleaning in multiple stages may be performed using different kinds of cleaning liquids. The present invention is not limited to the plating module 512 of the above structure. That is, the plating tank may be of other type such as a cup type or a closed type. In this case, a cleaning tank and a dryer may be provided separately. On the other hand, as shown in FIG. 30, the transport robot 514 has arms 542 having forward ends on which respective robot hands 540 are provided.

Next, the operation of the whole of this plating apparatus will be described. First, the robot hand 540 withdraws the substrate W before treatment from one of the wafer cassettes 510, and places it on a substrate holding portion 521 of one of the plating modules 512. Then, the plating module 512 performs a series of plating treatments as stated above, and dries the substrate W. The dried substrate W is returned again to one of the wafer cassettes 510 by the robot hand 540.

The substrate W before treatment and the substrate W after treatment pass through around the transport robot 514. In order to measure the film thicknesses of both substrates W, in the following embodiments, film thickness sensors S are provided at the transport robot 514 itself or in its surroundings, or at a position, such as the interior of the plating module 512, where the substrate W before treatment and the substrate W after treatment will pass through. Examples of the location and state of installation of the film thickness sensor S will be explained later in summary, and detailed explanations are omitted here.

That is, if the film thickness sensor S is provided at these

positions, the film thicknesses of the substrate W (the film thicknesses of all multi-layer metal films formed on the substrate W) before treatment and after treatment can be measured, without wasteful operations during a series of treatment actions. Specifically, when the substrate W passes through the film thickness sensor S for the first time, for example, the film thickness of the substrate W with the seed layer on its surface before plating is measured. When the substrate W passes through the film thickness sensor S for the second time, the film thickness of the substrate W with a metal film plated on the seed layer is measured. If a difference between the two film thicknesses is found, the plated metal film thickness can be measured. Generally, the film thickness of the seed layer is in the range of about several tens of nanometers to 100 and tens of nanometers, while the thickness of the plated metal film is about several micrometers.

Signals from the film thickness sensor S are sent to an arithmetic unit where an arithmetic operation, such as calculation of a difference or calculation of a moving average, is performed for thereby measuring the film thickness. The arithmetic unit and the arithmetic method may be arbitrarily selected ones which are preferred for the location of the film thickness sensor S, its detection method, and the like.

FIG. 31 is a plan view showing an example of a CMP apparatus to which the present invention is applied. This CMP apparatus comprises wafer cassettes 531, 531 for loading and unloading, cleaning machines 533, 533, 535, and 535 for cleaning substrates, two transport robots 514a, 514b, reversing machines 539, 539, and polishing units (substrate processing modules) 541, 541.

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There are various flows of substrates W, and an example is as follows: First, the transport robot 514a withdraws the substrate W before treatment from one of the wafer cassettes 531 for loading, and transfers it to one of the reversing machines 539. The transport robot 514a only rotates without moving from the illustrated position, and is disposed at a position where it can transport the substrate W from the wafer cassette 531 to the reversing machine 539. The substrate W has its surface, to be treated, changed by the reversing machine 539 from an upwardly facing state to a downwardly facing state, and is then transferred to another transport robot 514b. The transport robot 514b transfers the substrate W to one of the polishing units 541 where a predetermined polishing is performed. The substrate W after polishing is transported by the transport robot 514b to one of the cleaning machines 535 where primary cleaning is conducted. The substrate W after primary cleaning is transported by the transport robot 514b to one of the reversing machines 539 where its treated surface is turned over to face upward. Then, the substrate W is transported by the transport robot 514a to one of the secondary cleaning machines 533. After secondary cleaning is finished, the substrate W is contained again by the transport robot 514a in the wafer cassette 531 for unloading.

Therefore, in case of this CMP apparatus, the substrate W before treatment and the substrate W after treatment pass through near the transport robots 514a, 514b and the reversing machines 539, 539. In order to measure the film thicknesses of both substrates W, in the following embodiments, the film thickness sensor S is disposed at a position where the substrate W before

treatment and the substrate W after treatment will pass, such as at the transport robots 514a, 514b per se or the surroundings thereof.

That is, if the film thickness sensors S are installed at these positions, the film thicknesses of the substrate W before treatment and after treatment can be measured, without wasteful operations during a series of treatment operations. Specifically, for example, the film thickness of the substrate W before polishing is measured for the first time, and the film thickness of the substrate W after polishing is measured for the second time. If a difference between the two film thicknesses is found, the amount of polishing can be measured. Further, if an optical sensor is used, the film thickness of a metal film or an insulating film can be directly measured, without calculating the difference.

In some CMP apparatuses, the transport robots 514a, 514b are movable in a direction of an arrow A shown in FIG. 31. The present invention is applicable to the CMP apparatus having the transport robots unmovable or movable.

FIG. 32 is a view showing a plating and CMP apparatus to which the present invention is applied. This plating and CMP apparatus is different from the CMP apparatus shown in FIG. 31 in that the plating module 512 shown in FIG. 9 is provided in place of one of the cleaning machines 533, and a spin dryer 534 is provided in place of another cleaning machine 533.

The flow of a substrate W is, for example, as follows: First, the transport robot 514a withdraws the substrate W before treatment from one of the wafer cassettes 531 for loading. After plating treatment is performed by the plating module 512, the transport

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robot 514a transfers the substrate W to one of the reversing machines 539, which directs its treated surface downward. Then, the substrate W is transferred to the other transport robot 514b. The transport robot 514b transfers the substrate W to one of the polishing units 541 in which predetermined polishing is performed. The substrate W after polishing is withdrawn by the transport robot 514b, and cleaned by one of the cleaning machines 535. Then, the substrate W is transferred to the other polishing unit 541 where it is polished again, and the substrate W is transported by the transport robot 514b to the other cleaning machine 535 where it is cleaned. The substrate W after cleaning is transported by the transport robot 514b to the other reversing machine 539 where its treated surface is turned over to face upward. Then, the substrate W is transported by the transport robot 514a to the spin dryer 534 in which spin-drying is carried out, and the substrate W is accommodated again by the transport robot 514a in the wafer cassette 531 for unloading.

With this plating and CMP apparatus, therefore, a film thickness sensor S is installed at a position where the substrate W before treatment and the substrate W after treatment will pass, such as at the transport robots 514a, 514b per se or the surroundings thereof, or the interior of the module 512.

Next, a concrete example of the sensor S for film thickness measurement to be installed in the above-mentioned plating apparatus or the CMP apparatus will be described.

FIG. 33 is a perspective view showing the transport robot 14 illustrated in FIG. 30, and the transport robots 514a, 514b illustrated in FIGS. 31 and 32. FIGS. 34A and 34B are views showing

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a robot hand 540 attached to the transport robot 514 (514a, 514b), and FIG. 34A is a plan view and FIG. 34B is a side sectional view.

The transport robot 514 (514a, 514b) is constituted by attaching the robot hands 540, 540 to the respective front ends of two arms 542, 542 attached to an upper portion of a robot body 543. The two robot hands 540, 540 are arranged so as to be placed vertically one above the other via a predetermined gap. The arms 542 extend and contract to enable a substrate W placed on the robot hand 540 to be transported in a fore-and-aft direction. Also, the robot body 543 rotates and/or moves to permit transportation of the substrate W in an arbitrary direction.

As shown in FIGS. 34A and 34B, four film thickness sensors S are directly attached, in a buried state, to the robot hand 540. Any film thickness sensor S may be used, if it can measure the film thickness. Preferably, an eddy current sensor is used. The eddy current sensor generates eddy currents, and detects the frequencies and losses of electric currents which have passed through the substrate W and returned, thereby measuring the film thickness. The eddy current sensor is used in a non-contact manner. An optical sensor is also preferred as the film thickness sensor S. The optical sensor irradiates a sample with light, and can directly measure film thickness based on information on reflected light. The optical sensor is capable of measuring film thickness of not only a metal film, but also an insulating film such as an oxide film. The positions of installation of the film thickness sensors S are not limited to the illustrated positions, and the film thickness sensor S is attached in an arbitrary number at a location where measurement is to be made. The robot hand 540 is

available as a dry hand handling a dry substrate W, or as a wet hand handling a wet substrate W. The film thickness sensor S can be attached to either hand. When the transport robot 514 is used in a plating apparatus as shown in FIG. 30, however, there is need to measure the film thickness of the substrate W in such a state that only the seed layer is initially provided. Thus, it is necessary to measure the film thickness of the substrate W, initially in a dry state, which is placed in the wafer cassettes 510, 510. Hence, it is desirable to attach the film thickness sensor S to the dry hand.

Signals detected by the film thickness sensors S are sent to an arithmetic unit where an arithmetic operation, such as calculation of a difference between the film thickness of the substrate W before treatment and the film thickness of the substrate W after treatment, is performed and the film thickness is outputted onto a predetermined display or the like. Any arithmetic method may be used, if it can measure the film thickness appropriately.

According to the present embodiment, since the film thickness can be measured while the robot hand 540 is transporting the substrate W, there is no need to provide a film thickness measuring step separately during the substrate treatment process, and the throughput is not decreased. Since the film thickness sensors S are attached to the robot hand 540, a space saving can be actualized.

FIGS. 35A and 35B are views showing the transport robots 514, 514a and 514b illustrated in FIGS. 30 and 31 to which the second example of the present invention has been applied. FIG. 35A is a schematic plan view, while FIG. 35B is a schematic side view.

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As shown in FIGS. 35A and 35B, according to this embodiment, five film thickness sensors S are attached to a lower portion of the robot hand 540 of the robot body 543. That is, a disk-shaped mounting plate 545 of substantially the same size as the substrate W is installed at the lower portion of the robot hand 540, and the five film thickness sensors S are attached onto the mounting plate 545. The mounting plate 545 is fixed to the robot body 543, but may be fixed to other members.

The film thickness sensors S are attached at positions where the film thickness sensors S do not overlap with the robot hand 540 as illustrated, whereby the film thickness can be measured in a wide area of the entire substrate W. The present embodiment can also achieve a space saving, and can perform measurement in a very short time. By stopping the substrate W on the mounting plate 545, measurement of the film thickness at fixed points of the substrate W can be made. If the substrate W on the robot hand 540 is caused to pass over the mounting plate 545 without stopping, measurement during scanning becomes possible. Since the film thickness sensors S are integral with the robot body 543, stable detection can be performed. If the mounting plate 545 is fixed to other members, rather than the robot body 543, it becomes possible to adjust the distance between the substrate W and the sensors by arbitrarily varying the height of the robot hand.

The construction in which signals after detection are sent to the arithmetic unit to measure the film thickness is the same as in the embodiment shown in FIGS. 34A and 34B. However, in the case of measurement simultaneous with scanning, the points of measurement change with the passage of time, so that it is preferred

to perform computations by the method of moving averages and calculate the film thickness.

FIGS. 36A and 36B are views showing a third example of the present invention. FIG. 36A is a schematic plan view, and FIG. 36B is a schematic side view. In the embodiment shown in FIGS. 36A and 36B, three film thickness sensors S are provided on an upper portion of an exit and entrance portion 550, for a substrate W, of the plating module 512 shown in FIGS. 9 and 30. That is, a rectangular mounting plate 551 is disposed above the exit and entrance portion 550, and the three film thickness sensors S are attached in series to a lower surface of the mounting plate 551. The mounting plate 551 may be fixed to the plating module 512, or may be fixed to the robot body 543 of the transport robot 514 (not shown), or may be fixed to other members.

According to such a constitution, the film thickness sensors S scan the substrate W when the substrate W is placed into and withdrawn from the plating module 512. This is suitable for scan measurement. By providing some rows of the film thickness sensors S as in this embodiment, moreover, arbitrary points on the substrate W can be measured by scanning. By arbitrarily varying the height of the robot hand, furthermore, it becomes possible to adjust the distance between the substrate W and the sensors.

Signals detected by the film thickness sensors S are computed by an arithmetic unit. In the case of scan measurement, it is desirable to perform computation by the method of moving averages as in the second example.

When this embodiment is applied to the CMP apparatus, the film thickness sensors S may be disposed near the exit and entrance,

where the substrate W is introduced and withdrawn, of the polishing unit (substrate treatment module) 541 shown in FIGS. 31 and 32. When the substrate W is carried into the polishing unit 541, the surface, to be treated, of the substrate W faces downward. Thus, it is preferred to dispose the film thickness sensors S on a lower side of the location of the polishing unit 541 where the substrate W is carried in (of course, even when the film thickness sensors S are installed on the upper side of such location, measurement of the film thickness is possible, but installation on the lower side results in a higher accuracy). After polishing is completed, the treated surface of the substrate W is in a wet state. The use of film thickness sensors capable of measurement even in a wet condition makes it possible to measure the film thickness by the same method as in the plating module 512.

FIG. 37 is a schematic front view of a reversing machine 539 and its surroundings to which a fourth example of the present invention has been applied. FIG. 38 is a plan view of reversing arm 553, 553 portions. As shown in FIGS. 37 and 38, the reversing arms 553, 553 put a substrate W therebetween and hold its outer periphery from right and left sides, and rotate the substrate W through 180°, thereby turning the substrate over. A circular mounting base 555 is provided immediately below the reversing arms 553, 553 (reversing stage), and a plurality of film thickness sensors S are provided on the mounting base 555. The mounting base 555 is adapted to be movable upward and downward by a drive mechanism 557.

During reversing of the substrate W, the mounting base 555 waits at a position, indicated by solid lines, below the substrate

W. Before or after reversing, the mounting base 555 is raised to a position indicated by dotted lines to bring the film thickness sensors S close to the substrate W gripped by the reversing arms 553, 553, thereby measuring the film thickness.

According to the present embodiment, since there is no restriction such as the arms 542 of the transport robot 514, the film thickness sensors S can be installed at arbitrary positions on the mounting base 555. Further, the mounting base 555 is adapted to be movable upward and downward, so that the distance between the substrate W and the sensors can be adjusted at the time of measurement. It is also possible to mount plural types of sensors suitable for the purpose of detection, and change the distance between the substrate W and the sensors each time measurements are made by the respective sensors. However, the mounting base 555 moves upward and downward, thus requiring certain measuring time.

FIG. 39 is a sectional view of an essential part of a plating module 512 to which a fifth example of the present invention has been applied. This plating module 512 is different from the plating module 512 shown in FIG. 9 in only that a mounting base 559 having film thickness sensors S mounted thereon is installed immediately below a location of a substrate holding portion 2-9 where a substrate W is held (i.e. a plating stage). The film thickness sensors S may be installed at arbitrary locations on the mounting base 559.

In the present embodiment, the film thickness sensors S are mounted immediately below the plating stage, so that the film thickness measurement can be made on a real-time basis while plating is being performed. Thus, if the results of the measurement are

fed back in real time and reflected in plating, it is possible to perform plating with an extremely high accuracy.

The embodiments of the present invention have been described above, but the present invention is not limited to these embodiments, and various modifications are possible within the scope of the claims and within the scope of the technical ideas described in the specification and drawings. That is, the above embodiments have been shown as embodiments in which sensors for detection of film thickness (film thickness of a metal film or an insulating film) are used as the sensors. However, the present invention is not limited to these sensors. By selecting sensors and computation means according to various purposes, it is permissible to constitute and use other various sensors for substrate surface state detection, such as a sensor for detection of presence or absence of a metallic thin film, a sensor for detection of presence or absence of particles on a substrate, and a sensor for recognition of a pattern formed on a substrate. Furthermore, any shapes or materials, which are not directly described in the specification and drawings, fall within the scope of the technical ideas of the present invention, if they exhibit the operations and effects of the present invention.

As described in detail above, according to the third aspect of the present invention, various substrate surface states such as the metal film thickness of the substrate can be detected without stopping or interrupting the substrate treatment process. Thus, the surface state of the substrate can be detected, with high throughput being actualized, and the reliability and rapidity of substrate treatment such as plating or polishing can be increased.

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Further, feedback of the measurement results for adjustment of the substrate treatment conditions can be performed promptly, and hence it becomes possible to perform substrate treatment, such as plating or polishing, rapidly under optimal treatment conditions.

Furthermore, if a lightweight, and small-sized detection sensor is used, such sensor can be easily attached to a robot hand or the like of a plating apparatus, and the above-mentioned effects can be achieved with a space-saving.

The present invention relates to a semiconductor substrate processing apparatus and method for use in applying various treatments to a semiconductor substrate. The present invention can be utilized in a Cu plating step for forming interconnects on a semiconductor substrate, and in the step of polishing a plated Cu film on a semiconductor substrate in the manufacture of semiconductor devices.